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FORT KNOX, KENTUCKY

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REPORT NO. 13

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OBSERVATIONS WITH AGF TASK FORCES FRIGID AND WILLIWAW*

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MEDICAL RESEARCH AND DEVELOPMENT BOARD
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

RESTRICTED SECURITY INFORMATION

REPORT NO. 13

OBSERVATIONS WITH AGF TASK FORCES FRIGID AND WILLIWAW*

by

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from

Medical Department Field Research Laboratory
Fort Knox, Kentucky

12 January 1948

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ABSTRACT

OBSERVATIONS WITH AGF TASK FORCES FRIGID AND WILLIWAW

OBJECT

During the winter of 1946-1947 three observers from this laboratory conducted physiological observations on troops in the field at Task Force Frigid and Task Force Williwaw, and also on Eskimos at Barrow, Alaska. To enhance the value of cursory visual impressions, special tests under controlled conditions were performed. Information was obtained concerning problems of water balance and endurance, and also concerning the body temperature responses of Eskimos as compared with those of white men.

RESULTS

1. Pure-breed Eskimos maintained warmer finger temperatures than white men during the first 1 to 3 hours of exposure to outdoor weather under identical conditions. These results suggest values to look for in the preselection of men for arctic duty and in the assessment of acclimatization changes.

2. Twelve men in the field for 4 to 5 days maintained water balance at both Task Force Frigid and Task Force Williwaw, although water was available only from E rations and natural sources. In neither case, however, was the weather too severe or the equipment inadequate for the procurement of water. In some instances the urinary concentration of solids approached limiting values although the urinary volumes were moderately high. The potential importance of the water-balance problem is emphasized.

3. Measurements of blood and plasma specific gravities, hemoglobin concentration and hematocrit ratio were within normal ranges and did not show any hemoconcentration as a result of a winter's residence in the Arctic at Task Force Frigid.

4. Five of 9 men at Task Force Williwaw found conditions in a foxhole test unendurable for more than 16 hours, despite the fact that they showed no physiological responses significantly different from those of the 4 men who could have carried on longer. Psychophysiological factors seemed to limit endurance, as indicated by inhibition of hunger, tendency to feel cold and to become angry, and the tendency to sit and shiver rather than to move around to keep warm.

CONCLUSIONS

Cold can limit performance and endurance not only directly, but also indirectly, by causing other factors to become stresses. Dehydration, reduction of food intake, shivering, inability to sleep, extra work necessary to perform a task, all caused by the cold environment, can lead to reduced efficiency and exhaustion even though the body has suffered no significant temperature drop or decrement in dexterity. Minor stimuli,

e.g., wetness, reduced digital temperatures, uncomfortable posture, etc., can summate over a period of time to elicit psychophysiological reactions and subjective distresses which limit endurance. These induced stresses and additive stimuli will or will not make their appearance depending upon not only meteorological phenomena, but also the available equipment and facilities, available time, terrain, training, duration of field exercise, psychological characteristics of the individual and the group, etc. Because so many complicated factors are involved, it is hazardous to make generalized predictions or statements of any kind on the basis of temperature and wind alone.

There is little scientific information concerning such problems as preselection, acclimatization, endurance, survival, etc., as influenced by hypothermia. Empirical statements usually resolve themselves into personal bias based upon incomplete observations and personality factors. Exaggeration of conditions and accomplishments is often employed.

RECOMMENDATIONS

Although many problems can be studied only in the field, emphasis at this time should be placed upon laboratory development of techniques and concepts and accumulation of fundamental data. Many small field projects concerning physiological reactions to cold can be performed as well or better in the cold room as in the far North.

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(REPRINTED)

OBSERVATIONS WITH AGF TASK FORCES FRIGID AND WILLIWAW

INTRODUCTION

In July 1946 the Medical Department Field Research Laboratory was invited by the Army Ground Forces to send observers to Task Forces Frigid and Williwaw. The party selected consisted of one civilian scientist and two medical officers. The general objectives were to make general observations on the reaction of man to the environment and to obtain what data that could be acquired under the particular field conditions. Specifically the objectives were:

1. To ascertain the problems concerning the reactions of men in wet and dry-cold environments;

2. To describe the factors which limit performance and survival in these environments;

3. To acquire personal, first-hand experience of living in these environments.

It was decided that, since observers from other units of the Army would be concerned with problems of clothing and shelter, nutrition, sanitation, and general medical procedures, the party from this laboratory would direct its attention primarily to the physiological aspects of activities in the north country. Further thought on the matter led to the following conclusions:

1. That simple visual observation of men would yield only a very limited amount of information about physiology;

2. That measurements would have to be made to substantiate superficial impressions;

3. That measurements necessitate the use of instruments, which would have to be transported;

4. That measurements are usually meaningless, if there is no control over the situation.

For these reasons it was decided to collect the necessary instruments and to submit a request for 10 subjects, either to be taken along or to be furnished by the Task Forces. Great difficulty was experienced in procuring even the minimum of apparatus on short notice, and the request for test subjects was rejected because the Task Forces were limited both in manpower and in accommodations.

At this juncture the observers decided to run some tests on themselves in the cold room of the laboratory to see if it would be feasible to conduct similar observations on themselves in the field. These tests, in addition, served to accustom the observers to operating in the cold in heavy clothing, and to obtain basic data on themselves. It was soon learned, however, that three men would find it tremendously difficult to act as both test subjects and observers, and the prospect for making systematic measurements in the field seemed extremely remote. Nevertheless, preparations were continued in the hope that the Task Forces would find it possible to assign some men for certain tests.

As it turned out, both Task Forces very generously assigned test subjects. In addition, it was possible to conduct observations on Eskimos during the Christmas recess. Before describing these studies, however, the itinerary will be outlined briefly.

ITINERARY AND PROGRAM

Although arriving at different times, all the observers were signed in at Task Force Frigid on 2 December 1946. The thermocouple equipment however, was not delivered until 7 December, and the rest of the scientific apparatus shipped from Fort Knox did not arrive until after the observers had left for Barrow, Alaska.

December 2 to 22: The facilities for investigation available during this time were mainly those provided by the Medical Detachment, viz., a laboratory room with tables, sink with running hot and cold water, and a centrifuge. The thermocouple apparatus required repair of breakage sustained during transport from Fort Knox before it could be used. The repairs were completed just before the party left for Barrow.

The principal observations made during this period were cursory ones of men in quarters and in the field. The work of the ice-bridge crew, firing on the rifle range, the construction of the AAA tower, repair of vehicles, tank driving, etc., were observed. The field exercises planned by the Task Force for December were postponed because of the difficulties in constructing the ice-bridge, which was necessary for transporting heavy equipment to firing territory across the Tanana River.

In addition to the above activities, the observers also conferred with the Cold Weather Test Detachment at Ladd Field with respect to evacuation by helicopter and by glider. Considerable time was also put into preparation for the Eskimo studies.

December 22, 1946 to January 8, 1947: Investigations were conducted on the Barrow Eskimos as to their temperature responses to cold weather.

January 8 to 11: Preparations were made for the trip to Task Force Williwaw, both on a mountain maneuver and in foxholes.

January 11 to 30: Tests were conducted on 10 subjects on Task Force Williwaw, both on a mountain maneuver and in foxholes.

January 30 to February 9: The observers were detained at Anchorage on the return trip from Adak, because no planes were flying to Ladd Field due to the low temperature. The interval was utilized in preparing a preliminary report for Task Force Williwaw on the studies conducted on Adak.

February 9 to 26: Following the return to Task Force Frigid, only a limited amount of activity could be pursued because two of the observers were afflicted with acute upper respiratory infection. The preliminary report to Task Force Williwaw was completed and copies were forwarded to that force. In addition, preparations were made for field testing on men.

February 26 to March 4: Water-balance tests were conducted at Task Force Frigid on 10 subjects while living in bivouac. Additional tests planned for the subsequent five days could not be carried through due to the breakdown of the thermocouple potentiometer. The whole test program, therefore, was terminated on March 4 and the observers returned to Fort Knox. Before leaving they submitted a memorandum report on their activities to the Task Force officers.

RESULTS OF SPECIAL TESTS

The fundamental objective of all the tests was to obtain a description in quantitative terms of the physiological reactions of men while in the line of duty in the field. The nature of the control exercised in the field will be explained for each test separately. Special laboratory-type experiments were deemed out of place, except as they might prove worthwhile to check some observation made in the field. It was considered that the outdoors should be utilized, not as a laboratory room, but as an environment which could not be successfully duplicated indoors.

Despite the fact that much time has already been spent in analyzing the data, most of the conclusions in this report are to be considered tentative. Several of the individual problems will be tested by further experiments at Fort Knox and detailed reports will be submitted at a later date.

PART I

TEMPERATURE RESPONSES OF ESKIMOS TO OUTDOOR WEATHER

(with the collaboration of Major Harold L. Fruitman, SnC., and Lt. William C. Harstad, DC., USNR.)

I. INTRODUCTION

Physiological investigations on natives who endured the cold with great hardihood, are of value to the Army in that they may disclose physiological mechanisms which adapt a man to the Arctic. This knowledge could then be used, both in the preselection of men for arctic duty, and in assessing the adaptive value of any acclimatization changes that may be found to occur in white men following prolonged or repeated exposure to the cold.

The only available scientific studies relative to body temperature of natives in the cold are those of Hicks and O'Connor (1938) on the naked Australian aborigines. They found that when naked black and white subjects were cooled under identical atmospheric conditions, their skin temperatures fell to the same extent. Furthermore, these workers stated that the radial artery constricted in the natives after less cooling than in the whites. The natives apparently experienced as keenly as the whites the subjective sensations of cold when awake, but not when asleep (Goldby et al, 1938).

Despite these findings, the possibility still exists that the Eskimos may possess thermal responses different from those of white men. The basal metabolism of the Australian natives is apparently -12% to -30% (Wardlaw and Horsley, 1928; Wardlaw and Lawrence, 1932; Hicks et al, 1931, 1933, 1934). The basal metabolism of Eskimos, on the other hand, is +18% to +33% (Crile and Quiring, 1939; Heinbecker, 1928; Rabinowitch and Smith, 1936). (In another study in which the protein intake was reduced to half that in the first investigation, Heinbecker (1931) found that the basal metabolisms of his 4 Eskimo subjects were the same as the DuBois normal standards). If the basal metabolism of the Eskimo is really higher than the average basal metabolism of the white man, then the Eskimo could also be expected to sleep or rest quietly in the cold with greater comfort than white men. Heinbecker, (1932) also found that the fasting Eskimo does not exhibit the ketogenesis normally found among white men. If fat combustion is complete in the Eskimo, then the small Eskimo could compete with the large white man in combating the cold by a more effective utilization of stored energy. Obviously, the value of metabolic and biochemical studies on the Eskimo would be enhanced, if it could be shown that he also maintains body temperatures which adapt him to the cold better than the temperatures of white men do.

The opportunity to study the temperature responses of Eskimos presented itself when the troops were given Christmas leave. The commanding officer of Task Force Frigid arranged with the Navy to have the tests performed on the Barrow Eskimos. It had not occurred to the observers that these Eskimos might also be celebrating the Christmas season. Actually, they had a well organized program lasting over a week and the festivities considerably reduced the time available for test purposes. In fact, most of the test had to be run in the evening and had to be fitted into the general schedule when they would least interfere with the events of the week.

It is necessary to note briefly a few observations which have a bearing on the value of using the Barrow Eskimos as subjects for this investigation. It is often said that the white man has caused a negative alteration in the genetics and living habits of the Alaskan Eskimos. Even before the appearance of the white man, however, the Eskimo population of North America was probably not genetically homogenous(Shapiro, 1931). Hawkes (1916) found the Alaskan Eskimos to be larger and more robust than those of Eastern Canada. The admixture of white blood in the Eskimos of this study, as ascertained both by interrogation and by examination of the records of the U. S. Commissioner, is noted below. The present inhabitants of Barrow are recent immigrants (or their descendants) from places as far apart as St. Lawrence Island in the Bering Sea and the mouth of the Mackenzie River (Stefansson, 1938). In 1908, Stefansson found that no more than 7 per cent of the Barrow population belonged to the earlier tribe, which had died out. (At present there is no village at Point Barrow, which is about 14 miles northeast of Barrow.) The newcomers to Barrow adopted the white man's dwellings and other habits, and abandoned many of the former ways of living (described by Murdock, 1887). The houses which the observers visited were well-built frame structures heated by coal stoves; the measured temperatures 3 feet above the floor were about 72°F. Although living as white men do in their houses, the Barrow Eskimos still depend largely upon hunting and maintenance of a reindeer herd for their food supply, although a cash income may be obtained from the sale of pelts and ivory, and from employment by the Government. The population is still ravaged by tuberculosis, but Dr. E. S. Rabeau, of the government hospital there, did not believe that the Eskimos who acted as test subjects were afflicted by the disease.

II. EXPERIMENTAL

A. Design of the Tests

1. Basic Plan

a. To make valid comparisons between Eskimos and white men it was necessary that they be exposed under as nearly identical conditions as possible. This meant that the following conditions had to be fulfilled:

(1) Weather conditions had to be the same. Inasmuch as the exposures were to be in the uncontrollable weather of the outdoors, one white man was to be with the Eskimos in each test. (The paucity of white subjects made it impossible to have more than one in a test.)

(2) Clothing had to be the same for all men. Hence, army uniforms were taken up from Task Force Frigid to clothe the Eskimos.

(3) Activity had to be the same. It was desired that two extremes of activity be utilized - quiet sitting and brisk walking. Only the sitting tests, however, were performed. Shivering was not considered as activity, but as an adaptive response to the cold.

(4) The physiological state should be the same. Because the Eskimos both worked and attended their festivities, it was out of the question to try to exercise any control over eating, sleeping, and exhaustive work prior to the test. All that could be done was to take the men as they presented themselves and enter a few notations about their preceding activities. In addition, a simple cardiovascular test was performed just before each exposure to get some index of the physiological state.

b. In case the Eskimos in army clothing showed no temperature responses different from those of the white men, it was planned to have in each test one Eskimo in his own fur clothing, to see if it is their clothing which enables them to stay in the cold. Thus, there were to be in each experiment one white man and one Eskimo, each in army clothing, and one Eskimo in fur clothing. The experiment was then to be repeated on the same men, but with the Eskimos having their clothing changed; i.e., the one who had had the army uniform on in the first test was to wear his fur clothing in the second test and vice versa. If fur clothing could be procured, the white man was to wear it in the second test.

This plan may be criticized on the grounds that, since no control could be exercised over the weather, the second experiment would not be a true check on the first one. This criticism is acknowledged. Yet, there is this value to the plan: it does exercise control over the clothing variable. The conclusions are then drawn, not from the responses of one man in two different garments in two experiments, but from the relative picture of three men in one test compared with the relative picture of the same three men in the second test.

As it turned out, the plan could not be carried through. In the first place, in only 4 tests could it be arranged to have two Eskimos in each. In 2 of them both wore the army uniform because neither one brought along the full regalia he usually wore on the trail. In the other 2 tests the Eskimo wore either army or fur clothing. In the second place, only 4 of the Eskimos could arrange or would volunteer for a second test, but in no case could they be paired with the same men as in the first test.

2. Procedure. The same procedure was followed in all tests, except that the weight and linear measurements were made only the first time a particular man acted as subject.

a. The subject stripped and his nude weight and height were measured on a clinical scale in the hospital.

b. He then lay down and the linear measurements necessary for computing regional surface areas by DuBois' formulas were made with a tape measure.

c. The subject then covered himself and relaxed for 10 minutes or more, following which the pulse rate and brachial arterial pressure were measured, usually only once. The subject then stood for exactly one minute, and during the 1 to 1 1/2 minutes after standing the pulse and pressures were again measured.

In the actual performance, two factors occasionally intervened to militate against complete control.

(1) Although the hospital was always warm, it was not uniformly so. Therefore, not infrequently when the nude subject stood up from under his covers, his vessels responded, not only to the effect of gravity, but also to the sudden slightly cool feeling of the skin. Nothing much could be done about this matter as time and the other preparatory procedures necessitated that the subject be in the nude.

(2) The white subjects sometimes had difficulty in remaining quiet during the initial 10-minute rest period. Interruptions provoked vocal responses of various kinds which presumably could affect the heart rate. For this reason the white subjects had to lie on the bed for more than 10 minutes but, on the other hand, prolonged attempts at relaxation often led to restlessness.

d. The thermocouple harness was applied and the subject was assisted into his garments. If he was wearing fur clothing, notations were entered at this time as to each item worn.

e. The subject sat down and his skin and rectal temperatures were measured. This had to be done as quickly as possible, because a man in full arctic assembly soon starts to sweat at normal room temperature. As a rule the subject showed perspiration on his forehead before he went outdoors.

f. The subject went outdoors and sat down with his back to the prevailing wind. Thereafter temperature measurements were made on him as often as possible, and subjective reactions were noted periodically. It was desired that exposures last to the limit of endurance. This desire was not usually fulfilled for the following reasons:

(1) The subjects, both white and Eskimos, became bored with just sitting outdoors.

(2) The occurrence of a social event would make the men want to finish the test in a hurry.

(3) The observers, particularly the one who was operating the potentiometer, would become fatigued especially if the test lasted after midnight.

g. At the termination of the exposure the subject went inside, and as he undressed the status and location of each thermocouple was checked. Refreshments were served and the subject was interrogated.

B. Apparatus and Methods

1. Thermocouples. Copper-constantan thermocouples were applied to the skin by means of a harness devised by Palmes (1947). Since the couple is soldered to the middle of a brass screen, usually 5/8" by 2 1/2" in shape, the couple indicates the temperature of an area of the skin. In this manner the temperature was obtained on the plantar surface of the big toe and of the arch, anterior and posterior thigh, abdomen and lower back, and the volar surface of the distal phalanx of the large finger. In addition, a couple was placed on the exposed cheek by means of a wand about 2 to 5 minutes before the measurement. This couple gave the temperature of essentially the point of skin under it. The rectal couple was on the surface of a short plastic rod and was inserted 4 to 8 inches.

The leads from the couples terminated in the receptacle halves of Jones plugs. The extension lead ran from the potentiometer indoors through a port in the window to the outside. One observer then hooked up each subject in turn. As snow usually infiltrated into the receptacles of the plugs, the outdoor observer had to manipulate the halves of the plugs until contact was achieved. This could be communicated to him only by shouting through the window porthole. The rapidity and number of measurements which could be made were thereby reduced.

2. Potentiometer. The potentiometer was constructed at the Fort Knox laboratory in such a manner as to eliminate the use of a standard cell. (Exposure of a standard cell to low temperatures, even during transport, would make it unfit for further use.) Balance was indicated by a sensitive, portable galvanometer having a microscope.

3. Meteorology.

a. Air temperature was measured every 10 to 15 minutes with an exposed thermometer. Inasmuch as snow and frost often accumulated on the bulb producing unknown wet-bulb effects (which may have been negligible), it was decided to use the readings of the Weather Bureau station which was situated only 200 yards from the test site. As a rule, the two measurements agreed closely.

The subjects sat within the space encompassed by the L-shaped hospital, about 15 to 20 feet from the walls. The building was one story high. Thermocouple measurements showed that the temperatures of the walls and windows were slightly higher than the concurrent air temperature. This wall effect on radiant heat loss was considered negligible.

b. Wind velocity was measured every 10 to 15 minutes with an anemometer borrowed from the Navy. The graduations did not go lower than 3 knots. Also, it operated like an automobile speedometer and indicated instantaneous speed without totalizing the air movement over an interval of time. Thus, the average wind velocity could only be estimated roughly. Although a definite wind direction could usually be felt, there was also considerable turbulence due to the building. Hence, the anemometer was always held to one side of the subjects and at about head level. Air movement around the feet was probably less than that at the head.

c. Precipitation. No measurements or notations on snowfall were made. Very often the wind whipped up the snow and blew it around.

d. Sunshine and overcast. In December and early January the sun never rises above the horizon at Barrow. Moreover, practically all tests were performed after 1900 hours. No observations were made as to overcast, although sometimes the aurora was brilliant.

4. Clothing

a. The army clothing worn was that designated as uniform No. 6, and was the warmest army assembly. It was meant to be worn for an expected temperature of -60°F. The individual garments are itemized in Table 1.

Actually, this assembly provided more insulation than the Army prescribed for the air temperatures prevailing at Barrow. Using temperature as the sole criterion, the uniform No. 5 should have been used, which is to be worn when the minimum temperature expected is -35°F. and the maximum temperature is +15°F. It is not possible to change the No. 6 assembly in every detail to have the prescribed items of the No. 5 assembly. Although at Fairbanks, where wind is negligible, the air temperature criterion alone is adequate; at Barrow the cooling effect of the wind must also be considered. Therefore, the uniform No. 6 was used.

b. Eskimo clothing. Five Eskimos wore their own clothing which they used in hunting and trapping. Their assemblies were not uniform in every detail but, as an example, the garments of one subject are itemized in Table 2.

Some notable features of the Barrow Eskimo clothing were:

(1) The undergarments are those of the white man and usually made of cotton.

(2) Only the outer garments are made of fur.

(3) The parkas do not extend downward as an apron in front and back, as usually seen in pictures or museum displays of Eskimo clothing. The Barrow Eskimo places a piece of fur on the snow or ice before sitting down. (This we were told by them but never observed.)

(4) The fur trousers end in a 2 to 3-inch band just below the knee and do not extend down to the ankles. It would be impossible to expose the knees by pulling the trousers upwards.

(5) The fur trousers may be tailored to form a pocket-like bulge over the knee. Thus, the air layer is not pressed out in the sitting position.

c. It is difficult to form a satisfactory mental comparison of the army and Eskimo clothing by merely reading the lists in Tables 1 and 2. Moreover, the number of pieces put on do not indicate the amount of covering over the junctional regions where there is overlapping. For example, the waist is covered by both the upper and lower garments. The skin over the upper abdomen, therefore, would be expected to be warmer than the skin over the thigh, even if the heat flow to both places were the same. To facilitate the comparison of army and Eskimo clothing, the number of layers covering different parts of the body is given in Table 3.

TABLE 1

OFFICIAL UNIFORM NO. 6, TASK FORCE FRIGID

<u>Upper Garments</u>

1. Undershirt, wool, 50%, OD
2. Shirt, flannel, OD, coat style
3. Sweater, wool, OD, high neck
4. Jacket, field, pile, OD
5. Parka, field, pile, OD
6. Parka, field, cotton, OD

<u>Lower Garments</u>

1. Drawers, wool, 50%, OD
2. Trousers, field, wool, OD, serge, 18 oz. sp
3. Trousers, field, cotton, OD, w/suspenders
4. Belt, web waist

<u>Footgear</u>

1. Socks, wool, cushion sole (1 pr)
2. & 3. Socks, wool, ski (2 pr)
4. Socks, felt (1 pr)
5. Insoles, felt (1 pr)
6. Boots, mukluk

TABLE 1 (continued)

Handgear

1. Mitten, insert, wool, trigger finger
2. & 3. Mitten, Arctic (contains an insert)

Headgear

1. Cap, field, pile, OD (flaps down except on forehead)
2. Hood, parka, pile with fur ruff
3. Hood, parka, cotton

TABLE 2

EXAMPLE OF ESKIMO CLOTHING

Upper Garments

1. Undershirt, cotton
2. Shirt, cotton, cambric
3. Parka, caribou, fur in, lined
4. Parka, caribou, fur out

Lower Garments

1. Drawers, cotton
2. Trousers, cotton, gabardine
3. Trousers, caribou, fur out
4. Belt, leather

Footgear

1. Socks (1 pr)

   a. Caribou, fur in, on soles
   b. Sheep, fleece in, from middle of lower legs down over dorsum of feet

2. Mukluks, caribou

   a. Leg portion, fur out
   b. Soles, fur in

Handgear

1. Mittens, fawn, fur in
2. Mittens, dog, fur out

Headgear

1. Hood, parka, caribou, fur in, lined, wolverine ruff
2. Hood, parka, caribou, fur out, wolf ruff

TABLE 3

LAYERS OF CLOTHING

	Army Uniform No. 6	Eskimo
Thorax	6	4
Waist	9	7
Lower Abdomen and Back	5	5
Thighs		
Upper	5	5
Lower	3	3
Legs	4	3
Above Ankles	7	3
Ankles and Dorsum of Feet	5	2
Soles	6	2
Arms	6	4
Distal Third of Forearms	9	6
Hands and Wrists	3	2
Head	3	2

Clothing provides insulation by trapping air, both in the fibers and meshes of the fabric and also between the layers of fabric. Table 3 compares only the number of layers of fabric. Clearly, there are more layers in the army than in the Eskimo assembly, chiefly because of the sweater, pile jacket, and the several pairs of socks. (The active white man may shed some of the items of clothing to avoid sweating.) If both assemblies provide the same amount of insulation, it follows that fur provides a thicker mesh of trapped air than the material of the army uniform.

d. One more fact about clothing must be described. On the first day of testing (27 December), the subjects sat outdoors on uncovered metal chairs. Considerable cooling of the buttocks and posterior thighs took place by conduction, as attested by both the subjective sensation of pain in the buttocks and low thigh temperatures. On all subsequent days a navy wool blanket folded into 16 layers was placed on the seat of each chair. The buttocks were no longer painful and the thigh temperatures fell only a little.

5. Test Subjects

A total of 5 white men and 10 Eskimos took part in the tests. Two more Eskimos had volunteered but they contracted upper respiratory infection before their scheduled day and were not used. One white man was a Norwegian and claimed to have lived in the North country all his life. He was an outdoor worker for the Navy. The other four white men had spent only two to six weeks in the Arctic prior to the test, although one was in the Yukon Territory during 1942-43.

Certain data about the physical aspects of the subjects are given in Table 4. Attention is called to the following facts:

a. Only 7 men were pure Eskimos; two were 3/4 Eskimo and 1/4 white; one was 1/2 Eskimo, 1/2 white.

TABLE 4

PERSONAL DATA ABOUT TEST SUBJECTS

Name	Age years	Weight pounds	Height inches	Surface Area sq. meters	Weight S.A. kgm/sq.m	Occupation
ESKIMOS						
Bert Ahmaolik	38	154.	65.	1.76	39.77	Hunter
Noah Itta	27	155.	68.5	1.84	38.32	Hunter
Clay Kaigeluk	31	140.5	65.	1.71	37.35	Hunter
Hoover Koonaloak	28	161.	66.	1.83	41.73	Pfc, USA, Hunter
Ned Nusunginya	48	145.3	63.3	1.69	39.05	Outdoor labor for Navy
Nathaniel Olemaun	30	160.3	67.	1.84	39.60	Pfc, USA
Fred Ipalook	36	176.	63.8	1.85	43.24	School Teacher; does not hunt
Alfred Hopson[1]	48	150.8	67.	1.80	38.08	Hunter
Eddie Hopson[2]	26	147.5	66.5	1.77	37.88	Outdoor labor for Navy
Harold Kaveolok[3]	29	130.5	63.3	1.62	36.62	School Teacher for past year
MEAN	34	152.	65.5	1.77	39.17	
MEAN FOR PURE ESKIMOS	34	156.0	65.5	1.79	39.87	
1. Half white, half Eskimo (father an Englishman)						
2. One quarter white, three quarters Eskimo (mother is Eskimo)						
3. One quarter white, three quarters Eskimo (mother half Irish)						
WHITE SUBJECTS						
R.B.M.	26	182.9	72.	2.08	39.97	Captain, MC
E.L.D	30	155.3	69.5	1.87	37.74	Lieutenant, MC
H.L.F.	39	132.	66.	1.68	35.71	Major, SnC
W.C.H.	26	208.5	71.8	2.17	43.67	Lt., DC, USNR
F.H.	45	155.	67.3	1.82	38.71	Carpenter
MEAN	33	166.7	69.3	1.92	39.16	

b. Two of the Eskimos had sedentary occupations indoors; six were definitely outdoor workers. The duties of the two soldiers were not ascertained.

c. The white men were larger, on the average, than the Eskimos, but the mass per unit area was not significantly different between the two groups.

d. The percentage of the surface area over the different parts of the body was the same in the two groups. These regional areas were calculated according to the formulas of DuBois and DuBois.

C. RESULTS

A total of 9 tests on 7 different days was performed; 14 Eskimo exposures were obtained. They will not be discussed in detail in this report because experiments are now being conducted in the Fort Knox laboratory to determine how best to analyze the data obtained at Barrow. The initial superficial examination of these data did not disclose any consistent differences between the Eskimos and the white men. Further study, however, seemed to indicate that proper curve fitting was important. Illustrative measurements will be given to show the problems involved in the analysis.

1. Cardiovascular Tests. The data are presented in Table 5. The following arbitrary classification of physiological states was used:

a. Optimal - increment of pulse rate less than 10; decrement of arterial pressures not more than -2.

b. Sub-optimal - increment of pulse rate of 10 to 20 with decrement of pressures.

c. Poor - increment of pulse rate 20 to 30.

d. Very poor - increment of pulse rate more than 30.

Borderline cases were evaluated individually; for example, in Test No. 2, Noah was classed as sub-optimal, not as poor, because even though the increment of pulse rate was 20, the pressure increased by several millimeters.

On the basis of this arbitrary classification, the subjects started their exposures in the physiological states shown in Table 6. It appears that in four cases the white subjects were initially in a definitely poorer state than the Eskimos. In one test the Eskimo was in poorer shape than the white subject. In four tests the subjects were on about equal terms.

The term <u>physiological state</u> as used here is meant to denote the integral of internal factors which determine the efficiency with

TABLE 5

RESULTS OF CARDIOVASCULAR TESTS

Test No.	Date	Name*	Pulse rate			Arterial Pressures		
			Recumbent	Standing	Δ	Recumbent	Standing	Δ
1	27 Dec	Bert	66	80	+14	114/76/-	118/80/-	+4/+4/-
1	27 Dec	HLF	66	100	+34	118/74/-	114/72/-	-4/-2/-
2	27 Dec	Noah	78	98	+20	128/72/-	134/80/-	+6/+8/-
2	27 Dec	Alfred[1]	56	64	+ 8	117/74/-	118/76/-	+1/+2/-
2	27 Dec	RBM	100	124	+24	138/72/-	128/80/-	-10/+8/-
3	28 Dec	Clay	76	78	+ 2	132/74/68	144/84/80	+12/+10/+12
3	28 Dec	WCH	76	84	+ 8	117/72/64	122/80/72	+5/+8/+8
4	28 Dec	Ned	78	84	+ 6	116/74/68	114/76/68	-2/+2/0
4	28 Dec	Hoover	66	82	+16	126/78/64	136/88/82	+10/+10/+18
4	28 Dec	Eddie[2]	64	80	+16	110/-/64	115/78/68	+5/-/+4
4	28 Dec	ELD	80	86	+ 6	128/78/68	132/84/76	+4/+6/+8
5	30 Dec	Fred	80	104	+24	134/110/100	130/104/96	-4/-6/-4
5	30 Dec	Harold[2]	64	82	+18	119/82/50	117/80/68	-2/-2/+18
5	30 Dec	ELD	86	114	+28	118/72/68	118/84/78	0/+12/+10
6	31 Dec	Alfred[1]	72	66	- 6	128/72/60	138/84/76	+18/+12/+16
6	31 Dec	RBM	76	92	+16	128/74/58	122/80/60	-6/+6/+2
7	1 Jan	Nathaniel	76	80	+ 4	120/78/70	128/80/72	+8/+2/+2
7	1 Jan	ELD	80	102	+22	134/80/72	132/90/80	-2/+10/+8
8	4 Jan	Fred	66	92	+26	128/84/78	130/82/76	+2/-2/-2
8	4 Jan	HLF	80	88	+ 8	124/78/64	118/82/68	-6/+4/+4
9	5 Jan	Ned	68	86	+18	108/60/56	108/70/62	0/+10/+6
9	5 Jan	Eddie[2]	70	80	+10	122/72/55	118/78/60	-4/+6/+5
9	5 Jan	FH	72	98	+26	142/92/82	140/98/88	-2/+6/+6

*English names of Eskimos and initials of white men.

[1]Half white, half Eskimo.

[2]One quarter white, three quarters Eskimo.

TABLE 6

PHYSIOLOGICAL STATES OF SUBJECTS AT BEGINNING OF EXPOSURE TO COLD

Test No.	Date	Name*	Physiological State
1	27 Dec	Bert	Sub-optimal
1	27 Dec	HLF	Very poor
2	27 Dec	Noah	Sub-optimal
2	27 Dec	Alfred[1]	Optimal
2	27 Dec	RBM	Poor
3	28 Dec	Clay	Optimal
3	28 Dec	WCH	Optimal
4	28 Dec	Ned	Optimal
4	28 Dec	Hoover	Optimal
4	28 Dec	Eddie[2]	Optimal
4	28 Dec	ELD	Optimal
5	30 Dec	Fred	Poor
5	30 Dec	Harold[2]	Sub-optimal
5	30 Dec	ELD	Poor
6	31 Dec	Alfred[1]	Optimal
6	31 Dec	RBM	Sub-optimal
7	1 Jan	Nathaniel	Optimal
7	1 Jan	ELD	Poor
8	4 Jan	Fred	Poor
8	4 Jan	HLF	Optimal
9	5 Jan	Ned	Sub-optimal
9	5 Jan	Eddie[2]	Optimal
9	5 Jan	FH	Poor

* English names of Eskimos and initials of white men.
1 Half white, half Eskimo.
2 One quarter white, three quarters Eskimo.

which the organism can cope with a stress, and can be of transient duration. The term, <u>physical fitness</u>, usually connotes a somewhat permanent condition. Among the test subjects, Fred, who is a sedentary individual, was in both a poor physiological state and a poor physical condition. ELD, however, can be considered to have been in good physical condition but in a good physiological state only for his first test. Some of the internal factors which determine the physiological state are circulatory, respiratory, hormonal, nervous, muscular, digestive, etc., in nature. The circulatory state is the one most commonly used as an index. It remains to be proved, however, that the cardiovascular test here used bears a close correlation with one's ability to endure or cope with cold weather. It is possible that severe cold can elicit an adequate response even from one initially in a poor physiological state.

It is interesting to note that both Ned and Alfred have low arterial pressures for their ages (both 48 years old), whereas FH (age 45) has the expected arterial pressures. Rabinowitch (1936) quotes evidence that the Alaskan Eskimos apparently do not have arteriosclerosis, although he did find definite signs of it among the Eskimos of eastern Canada.

2. Body Temperatures. Figure 1 Shows the finger temperatures during exposure in Tests 1 and 2, both on 27 December. The air temperature was practically constant and the same for both tests, -23°F.(-30.5°C.). The wind velocity, however, was higher for the first test (about 11.5 mph.) than for the second test (about 7 mph.). In both of these tests the men sat on uncovered metal chairs. The rectal temperatures were essentially the same for all of the men. They are plotted, however, only for Bert and Alfred, and without showing the individual observed points.

Attention is called to the following details of Figure 1:

a. Noah, in army clothing, appears to have maintained a warmer finger than Bert in his own fur clothing. The difference, however, does not necessarily indicate that the army handgear is superior to the fur mitten, because Noah also started with a warmer finger. In another test, the Eskimo with fur mittens had a warmer finger than the Eskimo with army handgear.

b. Even allowing for Noah's high initial temperature, both he and Bert maintained significantly higher finger temperatures than the two white men (HLF and RBM) and Alfred in army clothing.

c. Alfred was in an optimal physiological state, yet his finger temperature was the same as those of the white men who were in a poor physiological state. (The curve for Alfred was not drawn because it lies almost exactly over the one for RBM, except for the last point.) Perhaps the cardiovascular test used is incapable of indicating one's potential for resisting the cold.

It is notable that Alfred is one-half white and one-half Eskimo, and also that when we first met him he informed us that he was more miserable in the cold than the other Eskimos.

d. Curves were fitted to the observed data by plotting them on semi-log paper and connecting them by straight lines. Equations of the type $Y = ab^X$ were then fitted by the method of least squares to those points which fell on or close to straight lines in the semi-log plot. For Noah, Alfred, HLF and RBM, there were 3 or 4 points each thus fitted to exponential curves. For Bert, however, two curves were fitted to two points each. Obviously, any kind of curve can be drawn through two points. The reason for drawing exponential curves through the points was that, according to Newton's law of cooling, the rate of heat flow from an object to its surrounding is proportional to the difference in temperature between them; i.e., the object cools exponentially. In some of the tests, however, the data seem to fit better to parabolic or hyperbolic curves than to exponential curves. Hence, before drawing final conclusions, the course of cooling in the Fort Knox laboratory under conditions simulating the Barrow tests is being measured at frequent intervals in order to determine how best to fit curves to the Barrow data.

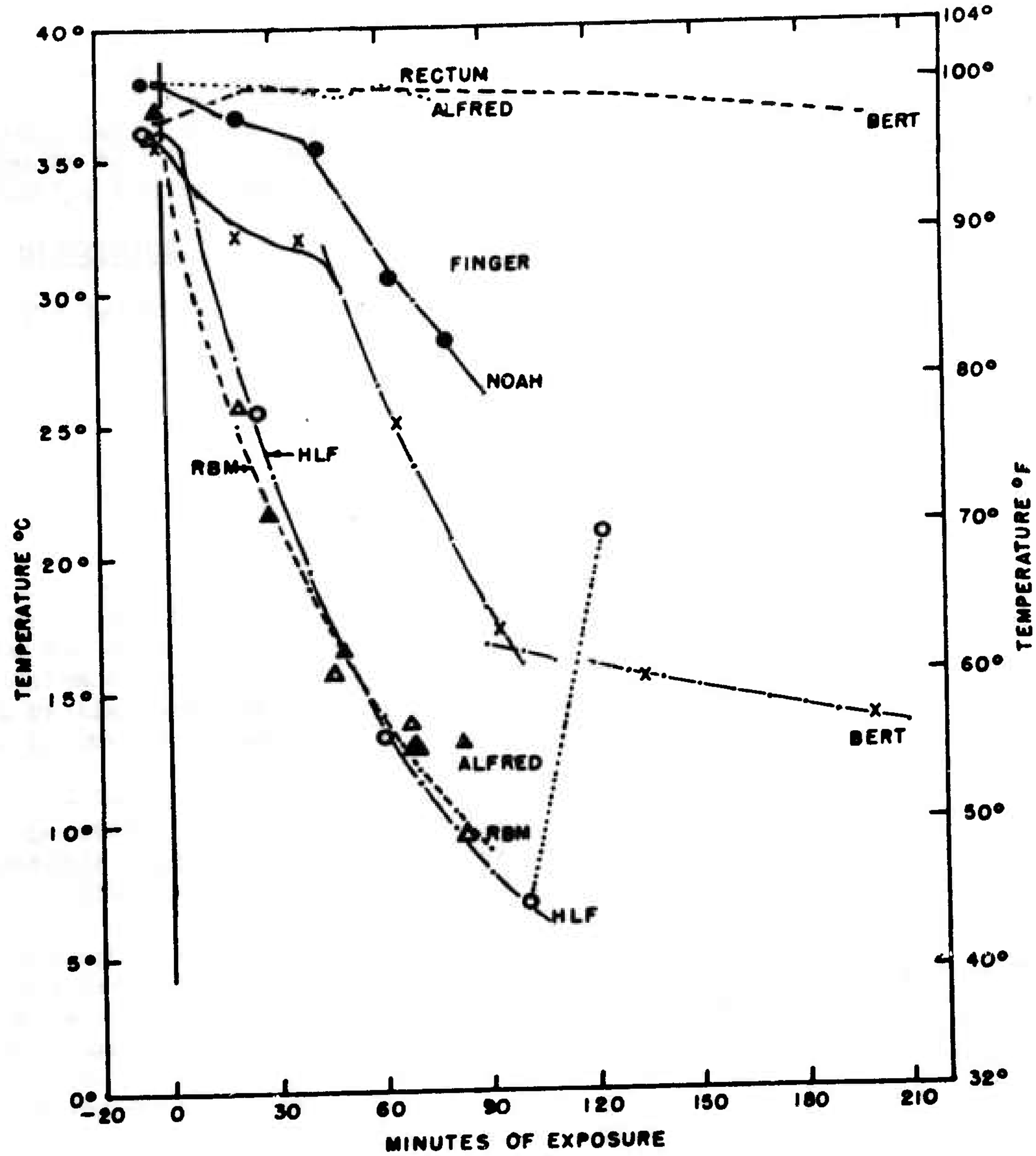

Fig. 1. Finger temperature during exposure to outdoor weather. Air temperature, -23°F. (-30.5°C.). Wind velocity, 7 to 11.5 mph. Tests 1 and 2, 27 December 1946.

X	Bert in fur clothing,	sub-optimal	physiological	state,	Test 1
●	Noah in army clothing,	" "	"	"	Test 2
▲	Alfred in army "	optimal	"	"	Test I
o	HLF " " "	very poor	"	"	Test 1
△	RBM " " "	poor	"	"	Test 2

The men went outdoors at zero time.

It is hoped that properly fitted curves will make it possible to locate with some accuracy the points of inflection which can be interpreted to indicate vasoconstriction or vasodilatation. For example, in the case of Bert the initial, gently falling, freehand curve suddenly falls steeply at about 45 minutes of exposure. This sudden change in the fall of temperature was probably due to vasoconstriction. Similarly, the inflexion at 95 minutes was probably due to vasodilatation.

III. DISCUSSION

The Barrow Eskimos gave the general impression that they were much happier in the outdoor cold than the observers were, both in the tests and in ordinary living. Some of the Eskimos felt that the conditions of the tests were almost as severe as any that they usually encountered. Although they too were often made uncomfortably cold, their subjective reports and general picture did not convey as much discomfort as shown by the white men.

The results of the tests indicate that, although during vasoconstriction the finger of an Eskimo cools at about the same rate as the finger of a white man, the Eskimo maintains a warmer finger than the white man during exposure by delaying vasoconstriction. The Eskimo's mechanism seems to leave him happier in the cold than the white man is left by his responses. It is emphasized that this interpretation of the data is purely tentative.

The Eskimos may have acquired their vascular responses to cold either by inheritance or by acclimatization. As to the influence of heredity, it is notable that Alfred, a half-breed, showed the same finger temperature as the white man (Fig. 1), and also claimed that he was not as comfortable in the cold as the other Eskimos. As to the influence of acclimatization, the Norwegian subject who said he had lived in the North all of his life did not keep his finger as warm as the Eskimo with whom he was paired, but did make a better showing than the other white men did. Furthermore, Ned (a full Eskimo) thought that after repeated exposure the white man came to endure the cold as well as, or even better than, any Eskimo. He based his conclusion on the observation that the white men working in the Navy camp at first wore heavy handgear, but subsequently could perform the same duties with only canvass gloves. He thought the white man was often better outdoors because he worked much harder than the Eskimo.

The investigators do not imply that their findings necessarily apply to all Eskimos and to all white men, but restrict their conclusion to only those who were studied. It is possible that there are white men who possess the Eskimo type of reaction to the cold or who may acquire it by acclimatization. The important point is that men who give every indication of great hardihood in the cold (in this study the pure-breed Eskimo outdoors-men of Barrow) maintain warm fingers for the first 1 to 3 hours of exposure. This observation is of value in lending direction to laboratory studies of acclimatization, and also in giving an indication as to the physiological characteristics to be considered in preselecting men for duty in the Arctic. Their greater comfort is ascribed to the relatively higher finger temperatures which they maintained in the cold.

IV. CONCLUSIONS

Full-breed Eskimos of Barrow appeared to bear the cold weather better than the white men paired with them. Their greater comfort is ascribed to the relatively higher finger temperatures which they maintained in the cold. This conclusion is tentative pending the analyses of similar tests performed on white men in the Fort Knox laboratory.

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PART II

WATER BALANCE STUDIES AT TASK FORCE FRIGID AND TASK FORCE WILLIWAW

I. INTRODUCTION

Th.. chief stress impinging upon men who are in the field in the Arctic is the cold weather. If, however, they are in the field continuously for several days, cold can cause other factors to become stresses and the physiological and psychological debilitations which arise may be due to these indirectly induced stresses instead of to the cold weather directly. These induced stresses may be fatigue and exhaustion due to constant work and shivering; insufficient sleep due to the inability to sleep in a cold tent; inanition and dehydration due to inability to eat and drink in the cold. Naturally, if all the comforts of home are taken into bivouac, the indirect stresses will not make their appearance. On the other hand, if the bivouac conditions are rugged and severe, all of the stresses should be taken into account and the physiological strains should not be laid to cold weather alone.

It is not a simple and easy matter to obtain significant physiological observations on men who are subjected to the rigors of the Arctic. Because facilities were necessarily limited, it was decided to center observations around the problem of water balance, which could be studied by adapting the methods used by Adolph in the desert (Adolph and Associates, 1947). The object was to see if men would keep themselves in water balance under conditions of no liquid water supply.

Water supply in the Arctic is a serious problem even if water is everywhere in the form of snow. Transportation of liquid water from a water point requires heated, insulated carriers. Men can, of course, melt snow if they have a stove and fuel but the stimulus to do so must be stronger than the stimuli of the environment which make the task a chore. Speert (1943), for example, thought that he and his party suffered from dehydration while in an isolated bivouac for a week on the Tanana River. His evidence was that everybody lost weight. It is, therefore, apparently quite possible, though not proved that men can go into negative water balance in the Arctic if forced to rely upon natural sources for water.

Dehydration in a comfortable environment produceds effects which may or may not occur in a cold environment, but which are instructive. Black, McCance and Young (1944) studied dehydration in men and women by withholding water. The subjects continued in their normal laboratory routine. By the end of 3 to 4 days they suffered 5 to 6 per cent dehydration, and "exhibited a change in behavior which could be interpreted as an exaggeration of their temperamental type. Serious people became positively somber; while others, normally cheerful, exhibited a somewhat hollow vivacity. The subjects were intellectually capable of performing estimations and calculations, but their concentration was impaired. They found that the days of dehydration were not actually uncomfortable but they seemed very long.

They were never unbearably thirsty, but by the third day their mouths and throats had become dry, their voices husky, and they had begun to find it difficult to swallow. By the third or fourth day their faces had become somewhat pinched and pale, and there was a suggestion of cyanosis about their lips which was rather characteristic."

At this juncture it is interesting to inquire how the Eskimos cope with the water problem. It is often said that Eskimos have a high water intake. "On one point only do they display a lack of moderation, and that is with regard to water drinking; a lot of water, and that ice-cold, is considered to be a necessity. This, however, is probably connected with their specialized meat diet, and the constant swilling undoubtedly saves them from a lot of rheumatism in their old age." (See Birket-Smith, 1935.) "The habitual drink is water, which these people consume in great quantities <u>when they can obtain it</u>, and like to have very cold. In the winter there is always a lump of clean snow on a rock close to the lamp, with a tube under it to catch the water that drips from it. This is replaced in summer by a bucket of fresh water from some pond or lake. When the men are sitting in their open air clubs at the summer camps there is always a bucket of fresh water in the middle of the circle, with a dipper to drink from. <u>Hardly a native ever passed the station without stopping for a drink of water, often drinking a quart of cold water at a time</u>. When tramping about in the winter they eat large quantities of ice and snow, and on the march the women carry small canteens of sealskin, which they fill with snow and carry inside of their jackets, where the heat of the body melts the snow and keeps it liquid. This great fondness for plenty of cold water has been often noticed among the Eskimo elsewhere, and appears to be quite characteristic of the race." (Murdoch, 1892.)

Can one literally believe these statements, and others comparable to them, made by non-physiologists? To our knowledge, nobody has yet measured systematically the water exchanges of Eskimos, and the only quantitative estimate of water intake that we have found is the one quoted above from Murdoch. There are two key statements in this quotation which we underscored. They suggest the possibility that the Eskimos appeared to drink a lot of water because, when they came before white men, they were already partially dehydrated and therefore quickly replenished the body deficit from the white men's supply of water. This possibility is not absurd, for Murdoch's senior officer wrote of the same expedition: "..... and as the season advanced and water became scarce we were daily besieged by the seal hunters coming from the sea and begging for a drink of water, of which there is a great scarcity after the frost has sealed up all sources of supply. The scarcity of fuel, together with their inadequate means for melting ice and snow, causes them to suffer under a constant water famine from October to July, and they seemed to think that our supply was never failing." (Ray 1885.) Anyone who has climbed the ice-hummocks of the Arctic Ocean to go seal hunting can appreciate that much sweat can be produced in this exertion.

Heinbecker (1928, 1931, 1932) obtained 24-hour urinary collections from 10 Eskimos on Baffin Island. For experimental purposes, the subjects were kept in the fasting state, but were allowed to drink water.

Hence, his data (473 to 2955 cc., average 1285 cc. per 24 hours) do not give a valid indication of normal water turnover among Eskimos. Rabinowitch and Smith (1936) found that urinary specimens (not 24-hour collections) from the Eastern Eskimos had low chloride concentrations and an average specific gravity of 1.015 (1.010 to 1.024). They ascribed the low urinary chloride concentration to the low salt content of a meat diet and to profuse sweating. We were unable to study the water economy of our Eskimo subjects, because the necessary equipment had not arrived from Fort Knox before we left for Barrow.

The above quotations emphasize that Eskimos prefer cold water. Other writers say that Eskimos drink hot tea. One of the Barrow Eskimos (Ned) informed us that when on the trail he drank warm coffee from a thermos bottle. He appeared to be amazed that we should consider such a reasonable procedure as extraordinary and unexpected.

There are three fundamental problems concerning water balance which need to be solved:

1. How well do men maintain their water balance when in the field in the Arctic, and what deleterious effects do they suffer from imbalance?

2. What factors (environmental, psychological, thermal, circulatory, renal, gastro-intestinal, and dietary) influence the turnover of water in cold environments?

3. What are the water requirements for different levels of performance?

Some aspects of these problems can best be attacked in the laboratory; others can be studied only in the field.

An army which operates from a comfortable garrison and merely sallies forth into the field for a few hours a day will not have to worry about water balance. At Frigid every small unit, which we visited and which worked outdoors only during the daylight hours, carried along coffee in an insulated container. This seemed to us an excellent practice. At Williwaw, coffee was prepared for the men both in the morning and in the evening, even though the tactical situation required that they subsist on field rations alone. Different men drank different amounts of this prepared coffee. The value of it was probably largely psychological. Physiological benefits probably also accrued, although the amount of heat added to the body in this manner is very small; 500 cc. of liquid at 50°C. will add only 6 or 7 Calories. It is possible that caffeine stimulates the central nervous system directly. We suspect, however, that stimulation comes from just warming the stomach, which reflexly produces a brighter outlook.

II. EXPERIMENTAL

A. General Design of Program

1. Total water intake and urinary output were to be followed in men continuously in the field. Obviously, if the men were to return every night to their barracks, there would be no problem of water balance.

2. The men would have to procure water for themselves from natural sources. Obviously again, if water were provided there would be no real problem.

3. The men would be free to drink as much water as they bothered to procure. The object was to see if they would maintain an adequate water intake and not to ascertain the effects of diverse amounts of controlled intake.

4. Because a significant amount of water might be in the food, all men would be on the same ration, preferably the Army Field E Ration, to facilitate a reasonable estimation of food water.

5. The major exertions of the men would have to be the same for all, but the milder forms of activity, including sleep, would not be controlled.

6. Dehydration, if any, would be deduced from changes in body weight, relative values of water intake and urinary output, and changes in blood specific gravity.

7. Physiological deterioration, if any, would be deduced principally from changes in heart rate following the performance of standard work.

8. If opportunity permitted, the observations would be performed on the men while in the barracks both before and after going out into the field.

9. Observations would be limited to ten men, because there were only three observers, and because the measurements had to be accurate.

With these ideas in mind, water balance observations were conducted with both Task Force Williwaw and Task Force Frigid. Because the conditions were not the same with the two Task Forces, a comparison of the results is instructive and interesting.

B. Materials and Methods

1. Water Intake.

a. Imbibed water. Each subject was provided with a graduated enameled cup and a pocket notebook. The men were instructed to measure all fluids and to enter the amounts drunk in their notebooks. The entries were repeatedly checked during the course of the test.

At Task Force Williwaw, water was obtained by breaking through the thin surface ice of a lake and dipping in with a cup. The water was thus icy. At first the hole was broken through with the heel but later an ax was used. It was necessary to walk about 200 to 400 feet to the lake, including embankment of about 20 feet. Thus the chief stimuli inhibiting the procuring and drinking of water were:

(1) The Distance necessary to traverse, including an embankment, to the source of water.

(2) The necessity for dislodging oneself from a more or less comfortable position (wind-break, tent, or sleeping bag) and exposing oneself to the wind. This stimulus was strong enough to inhibit some men from going for the hot coffee provided on two occasions.

(3) The nuisance of having to break through the ice. Actually, this was not much of a task but it was an annoying one in the wind.

(4) The almost inevitable slight wetting of one's handgear when dipping in for the water.

(5) The low temperature of the water. One does not drink much ice water, particularly if one already feels cool. Heating water for coffee took time and effort.

(6) The absence of a positive stimulus should be noted. The atmosphere of a small tent or of a windy out-doors is not conducive to drinking.

These inhibiting stimuli appear minor when considered singly, but together they summate to produce an effect that makes one pause before dashing out for water. No doubt, had we not been concerned with the water balance problem, we might have merely reacted to them but not noted their influence on the behavior of men.

At Task Force Frigid, water was obtained solely by melting snow. It was originally intended that each man be provided with a one-man gasoline (Coleman) stove. Only three could be procured, however, including one sent up from Fort Knox. As it turned out, these stoves were used for melting snow only for the noon meal when out on the march. The rest of the time snow was melted on two other stoves. One was a coal-burning, pot-bellied stove used for heating the pyramidal tent. Some of the men placed their cups containing snow on top of this stove and left them there until they desired to drink. The second stove was a gravity-feed, gasoline one. It had as a top a metal tray about 3 x 12 x 18 inches, and was provided as a facility for heating the E-ration, which was always frozen. The sergeant, however, spontaneously detailed a man each day to keep the tray filled with snow. Thus the men in the Frigid study had no real difficulty getting water.

b. Water content of food. E Ration was the only food eaten and the amount of each item was recorded in notebooks. The amounts of carbohydrate, fat, and protein in each item were obtained from Quartermaster food tables. The sum of these was subtracted from the weight of the food and the difference was assumed to be the water content. The E Ration tables also gave the caloric value of the food.

2. Urinary Output.

a. Each subject was provided with a conspicuously numbered one-half gallon can. A metal funnel and large handle were soldered to each can and a stopper with handle was chained to it.

b. Volume was measured in a liter-size graduated enameled cup. It was necessary to melt the urine before the volume could be measured.

c. Specific gravity was measured with a urinometer. Unfortunately, the spindles were not calibrated before use and they were broken before they could be later calibrated in the laboratory. Hence, the small temperature corrections which were made were perhaps of little value.

d. A sample of each 24-hour collection of urine was saved for later chloride analysis in the laboratory by a modified method of Van Slyke.

e. Total urinary solids were estimated on the basis of specific gravity and volume. Instead of using Long's coefficient (Long, 1903), his data were used to calculate a curve by the method of least squares. The curve was used in obtaining the values for solids.

3. Psychological Orientation.

The test subjects were not volunteers. Since the collection of the fundamental data had to be left to them, it was necessary to adopt measures which would insure the validity of the data. Although military command was, of course, the chief stimulus for keeping the men in hand, it was feared that reliance upon it alone would prove to be inadequate. For this reason the following additional tactics were employed:

a. Before going into the field the men were briefed with emphasis on the following points:

(1) That the test was important and would yield valuable information.

(2) That only by adhering rigidly to the directions of the test could results of value be obtained.

(3) That both the men and investigators were wasting their time and undergoing unnecessary misery unless the test was carried to a successful completion.

(4) That all men make mistakes but that all mistakes should be reported to the investigators.

b. During the course of the test, active cooperation was solicited by:

(1) The investigators exposing themselves to the same rigors as the men.

(2) Friendly and courteous greeting and frequent questioning about their welfare.

(3) Frequent checking on the little matters (Did the wind blow away some of your broken cracker before you could eat it?).

(4) Bothering to answer or comment upon many little questions and remarks.

(5) Trying to establish the impression and atmosphere that the test was something out of the ordinary and of great importance:

(a) The individual parts of the test were executed with organization and efficiency.

(b) Tremendous interest was always expressed in the data as they were gathered. In this way, the men themselves came to be interested in their weight changes, pulse rates, etc.

(c) The spontaneous appearance of high ranking officers was of great value in adding significance to the test.

4. Body Weight.

Body weights were measured in the nude on a scale accurate to ±10 grams. Unfortunately, the urinary bladder was not always certainly emptied prior to weighing. At Task Force Williwaw it was out of question to carry the heavy scale over the mountains, and the weights were obtained only just before and after the march. At Task Force Frigid the men were trucked to the dispensary and weighed about an hour after breakfast on four mornings.

5. Blood Analysis.

Elaborate analyses were out of question and only simple ones could be performed. Potassium-ammonium oxalate was used as anti-coagulant. Blood was drawn from the antecubital veins without stasis.

a. At Task Force Williwaw, only bottles of copper sulfate were available for measuring blood and serum specific gravities by the method of Phillips et al. (1945). Unfortunately, an error had been made in weighing out the salt and new bottles could not be made up. The results, therefore, are of no value.

b. At Task Force Frigid, blood samples were drawn during 1 to 1 1/2 hours after breakfast, except on day 5 in Bivouac when they were obtained before breakfast. The following measurements were made: (1) Plasma specific gravity by means of a dipping refractometer. Melted icicles were used for distilled water. (2) Blood and plasma specific gravities by the copper sulfate method. Corrections were made for the effect of the anticoagulant. (3) Hematocrit ratio: The samples were spun for 45 minutes in a large centrifuge. Sedimentation rates were obtained before centrifuging.

6. Meteorology.

a. Task Force Williwaw. Only dry-bulb temperatures were measured on the march and notations were made about sunshine, wind, and precipitation. The wind varied greatly from place to place. The following data summarize the daytime weather briefly:

Date	Air Temp.	Wind	Sky
16 Jan.	27.4°F.	Light	Mostly overcast
17 "	23.8°F.	Light	Sunny with passing clouds
18 "	27.7°F.	Strong	Mostly overcast
19 "	27.4°F.	Very strong	Completely overcast
20 "	22.0°F.	Strong	Mostly overcast

Whenever the sun was out one felt subjectively warmer. Although the air temperature was usually only a few degrees below freezing (never above freezing), a strong wind always cooled the resting man to the point of being uncomfortable. Precipitation was always snow, and it was sometimes difficult to tell whether snow was falling or merely being whipped around by the wind. At night the temperature fell to 18°F.

b. Task Force Frigid. Air temperature was measured, but the wind velocity was so low, usually less than one mph. at 4 feet above the ground (with a totalizing anemometer), that measurements were not made. During the 5 days in bivouac the air temperature was unseasonably warm. The following data summarize the weather:

Date	Air Temp. Day	Night (min.)	Sky
26 Feb.	32°F.	20°F.	Sunny, but bivouac in shadow of woods
27 "	30°F.	20°F.	Overcast, light snow till noon
28 "	28°F.	13°F.	Sunny in morning only
1 March	26°F.	5°F.	Brilliant sunshine
2 "	10°F.	-12°F.	Brilliant sunshine

7. Clothing.

No control could be exercised over the clothing variable, especially at Task Force Frigid because, at the time of the tests, the subjects did not have enough garments of the same kind to make up a uniform assembly suitable for the prevailing weather. In general, while on the march the clothing was approximately the same at both Task Forces:

a. Trunk, 3 layers, including ski parka.

b. Feet, 2 to 3 wool socks; shoepacs at Task Force Williwaw; felt or ski shoes at Task Force Frigid.

c. Hands, wool gloves with leather shell.

With this much clothing one tended to sweat on the march. In the morning and evening when not marching, the men also put on a wool sweater or pile jacket. At Williwaw the men slept in a mountain (single) bag; at Frigid in an Arctic (double) bag. As a rule, only a poncho (Williwaw) or wallboard (Frigid) was between the sleeping bag and the ground.

8. Shelter.

a. Task Force Williwaw. Shelter half-tents (2-man) were used, with no heat. When well secured these tents are satisfactory and were preferred by all of the men over the mountain tent.

b. Task Force Frigid. All test subjects were in a pyramidal tent with a wallboard floor. A coal-burning, pot-bellied stove gave sufficient heat to keep the men comfortable. At ground level it was not so warm and, since the fire eventually went out and the outdoor temperature dropped during the night, the men woke up in a cold environment.

9. Major Activity.

a. Task Force Williwaw. Marching over mountains was the major exertion, though not to the same extent for all of the 4 of the 5 days the men were out. The maximal ascent was 900 feet, and the packs were heavy (60 to 70 pounds).

b. Task Force Frigid. Marching on snowshoes (trail type) on the Tanana River was to have been the major activity. Actually, the first day had to be spent setting up the bivouac. On the second day the men marched for only 2 1/2 hours because they were not conditioned. On the third day it was necessary to be content with marching without snowshoes for 4 hours on a hard-packed road. On both of the last two days they marched for 4 hours on snowshoes on the Tanana River; i.e., it was necessary to break trail. Each man took his turn breaking trail for 10 minutes, but snowshoeing is hard work even for the last man in the column. The packs were light, as they contained only the noon meal and the three one-man stoves. The men also carried their measuring cups, urine cans, and rifles.

10. Pulse Rate.

a. Task Force Williwaw. It was impractical to measure the pulse rate while marching over the mountains.

b. Task Force Frigid. The radial pulse was palpated and timed with a stop watch. Initial rates were obtained in the standing posture just before setting out on the march. After marching for 50 to 60 minutes, one man was taken out of the column and, during the 1 to 1 1/2 minutes of standing still, his pulse was counted. In the meantime, the other men continued to march in a big circle at the same pace as before, and one by one they were taken out for the pulse count.

11. Test Subjects. Table 7 summarizes physical data about the men. On the average, they were of about the same size in the two tests.

TABLE 7

PHYSICAL DATA ABOUT TEST SUBJECTS

	WILLIWAW	FRIGID
Number of men	12*	11
Age, average	23**	20***
range	19 to 33	19 to 23
Initial weight, average	158.2 lb.	163.8 lb.
range	137 to 183	136 to 231
Height, average	69 inches	70.5 inches
range	65 to 72	66 to 75.5
Surface area, average	1.87 sq. m.	1.92 sq. m.
range	1.68 to 2.05	1.65 to 2.18
Weight/Area, average	38.52 kgm/sq.m.	38.53 kgm/sq.m.
range	36.4 to 41.5	34.6 to 48.1

*10 EM, 2 observers
** 9 EM, 2 observers
***10 EM (enlisted men)

C. Results

1. Water Balance

Table 8 summarizes the budget of water balance. For Task Force Williwaw only the data for the first 4 days that the men were in the field were used because, although they marched on the fifth day, they returned to quarters in the late afternoon and ate and drank that evening. The data for the interval on the fifth day just before reaching the garrison are abnormal in that most men did not bother to eat and drink much in their great haste to get back. One man did not eat or drink anything before the evening mess, and then drank over 2500 cc. (beverages) before going to bed. In both tests the men did not march on one day. Also, in both cases, the men ate breakfast in the mess hall on the first day of the march. Estimates were made of the composition of the recorded items of this meal on the basis of standard nutrition tables, and the results were included in the averages of Table 9. It should be noted that at Task Force Williwaw the general order commanded all men to carry a full canteen of water when starting on the first day. Some men did not comply with this order.

TABLE 8

BUDGET OF WATER BALANCE

Mean Values in Liters per Man per Day

	Williwaw 4 days	Frigid 5 days
Water Intake		
Drink	1.16	1.20
Food	0.75	1.13
Oxidation	0.32	0.48
Total Intake	2.23	2.81
Water Output		
Urine	1.27	1.20
Feces	0.10	0.10
Evaporation	1.08	1.54
Total Output	2.45	2.84
Water Balance	-0.22	-0.03
Weight Loss, kgm.	(-0.28)	-0.025

Table 8 was drawn up in the following manner:

a. Water Intake. All water available for exchange was assumed to have entered the organism by ingestion and by oxidation of only ingested food. This assumption carries the further implicit assumption that the men maintained caloric balance. The water that was drunk was measured by the men. The water in the food was estimated on the basis of recorded food intake and the E Ration composition table. The water of oxidation was calculated as shown in Table 9.

b. Water Output. Urinary volume was measured. Water in the feces was assumed to be 100 cc. The evaporative water loss was calculated by dividing the caloric intake by 2.32 (4 x 0.58 cal/gm water). The assumption that one-quarter of the total heat loss was by evaporation gives a minimal value, because one tended to sweat while marching.

c. Water balance is the difference between total intake and total output.

d. Weight loss at Frigid was obtained by measurement. As explained above, the final weights at Task Force Williwaw were obtained at a time which makes their utilization difficult. By making the gratuitous assumption that half of the total weight loss (2.22 kgm.) occurred on the fifth day prior to weighing, because the men ate and drank little and marched over the mountain, an equivalence between weight loss per day and negative water balance, $\frac{2.22 \text{ kgm}}{2} \div 4$ days, can be obtained.

TABLE 9

FOOD INTAKE

Mean Values per Man per Day

	Grams	Calories*	Water from Oxidation Grams**
Carbohydrate			
Frigid	519	2076	311
Williwaw	307	1228	184
Protein			
Frigid	140	560	56
Williwaw	107	428	43
Fat			
Frigid	108	972	116
Williwaw	90	810	96
Total			
Frigid		3608	483
Williwaw		2466	323

* grams carbohydrate x 4
grams protein x 4
grams fat x 9

**grams carbohydrate x 0.6
grams protein x 0.4
grams fat x 1.07

Attention is called to the following features of Table 8:

a. There was no significant water imbalance in either the Frigid or the Williwaw test. Even when the men are considered individually, the evidence is not conclusive that significant dehydration took place during the few days the men were in the field.

b. Only 40 to 50 per cent of the total water intake was obtained by drinking, 35 to 40 per cent was in the food, and about 15 per cent was produced by oxidation. Thus, although the men drank the same amount in both tests, the total water intake was less at Williwaw than at Frigid by about one-half liter per day, because the food consumption was much lower at Williwaw. (The mean caloric intake was about 1100 Calories more at Frigid than at Williwaw.)

2. Urinary Output

The data on urinary output are summarized in Table 10. They are of interest because when water intake is reduced the kidneys conserve body water by reducing the volume of urine and increasing the concentration of dissolved substances. On the other hand, the extent to which the urinary volume can be reduced is determined by the limit to which the kidneys can concentrate the urine (Adolph, 1923).

TABLE 10

URINARY OUTPUT AND PROTEIN INTAKE

Mean Values per Man per Day

	WILLIWAW 4 days	FRIGID 5 days
Volume, liters	1.27	1.20
Specific Gravity	1.023	1.027
Total Solids, gm.	72	81
NaCl, gm.	12.0	14.8
Protein Intake, gm.	107	140

Table 8 shows that there was a fair equality, on the average, between the volume of water drunk and the volume of urine excreted. The water supplied by food and oxidation was sufficient to balance the water lost by channels other than the kidneys. Therefore, so long as the food is no more concentrated than E Ration and enough is eaten to maintain caloric balance, men in the Arctic need drink no more than is necessary to form urine of the limiting concentration. It follows that the amount of water that must be drunk is determind principally by the amount of solutes obtained from the diet and from metabolism which must be excreted. (In the desert, water intake is determined largely by the amount of sweat secretion. This discussion for the Arctic holds only for conditions of minimal sweat formation.) In brief, the nature of the diet (high or low in water, salt, and protein) will go far in determining whether or not a man will dehydrate in the Arctic when water is difficult to obtain.

Although the average values of Table 10 for protein intake and urinary constituents are not very high, in individual cases the data suggest that urine of limiting concentration was being excreted, especially in the Frigid test. There were many instances of urinary specific gravity above 1.030; the highest obtained was 1.038. The highest chloride concentration was 296 meq./liter, equivalent to about 17 grams of NaCl per liter of urine, although for all of the men 15 grams per liter appear to have been the limit approached. Large amounts of solutes other than salt were also excreted (up to 127 grams of total solids per day); the principal item probably was urea. The greatest amount of protein ingested was about 300 grams in one day. The data suggest that about 1 liter of urine must be excreted for every 200 grams of protein ingested.

3. Hemoconcentration.

As explained above, the blood studies at Williwaw were unsuccessful. The results obtained at Frigid are shown in Table 11. It is evident that there was no hemoconcentration during the course of the test. The particular measurements made (specific gravity and hematocrit ratio), of course, do not disprove the possibility that blood dilution was maintained by the transfer of water from the cells to the blood stream. Analyses of blood Na and K might have shed some light but were not made. Because the measurements of water exchange do not indicate any dehydration it is concluded that no transfer of water from cells took place.

It is interesting to note that the values in Table 11 are not out of the range of normal values for men in comfortable environments. In other words, there was no obvious "thickening" of the blood of these men during the months they were in the Arctic.

TABLE 11

BLOOD DATA OBTAINED AT TASK FORCE FRIGID

Mean Values for 11 Men

Day in Bivouac	Blood Sp. Gr.	Plasma Sp. Gr.	Hematocrit Ratio-		Hemoglobin gm/100 cc.	Refractive Index Diff. x 10^5
			Calculated	Measured		
1	1.0586	1.0292	43.7	46.5	14.7	1828
3	1.0588	1.0298	43.5	46.8	14.7	1861
5	1.0594	1.0300	44.3	47.5	15.0	1826
7	1.0590	1.0297	43.9	46.7	14.8	1825

4. Pulse Rates

As indicated above, the increment of pulse rate resulting from the performance of standard work was to serve as an objective index of physiological fitness or deterioration. The work was to be marching at a standard pace. At Williwaw, the test was not performed and no pulse rates were obtained. Actually, there seemed to be no evident deterioration for on the last day the men marched back with great alacrity because of the universal desire to get back to quarters. At Frigid, the standard work was marching on snowshoes but the results do not show any evidence of deterioration.

Two factors militated against the usefulness of the test:

a. The men were not conditioned to marching on snowshoes.

b. Many of the men had upper respiratory infection which wore off gradually.

As a consequence of these two factors, the men seemed to show improvement on the last day instead of deterioration (Table 12). Actually, since the men maintained both caloric and water balance and were overcoming their initial state of illness and lack of experience, there is no reason why the pulse rate increments should have been greater on the last day of the test.

TABLE 12

INCREMENT OF PULSE RATE FOR MARCHES AT TASK FORCE FRIGID*

Per Cent of Initial Standing Rate
Mean Values for 11 Men

Hour of March	Day in Bivouac			
	2	3	4	5
1	49.8	15.8	30.6	36.5
2	47.3	24.5	45.3	18.1
3		—	28.8	—
4		23.5	43.9	37.3
5		34.7	—	49.4
6		36.5	47.5	

* On the 1st day in bivouac the men did not march. On the 2nd, 4th and 5th days they marched on snowshoes. On the 3rd day they marched on a hard-packed road. Pulse rates were counted at the end of each hour of march.

III. DISCUSSION

Under the conditions of the observations here reported men did not go into negative water balance. Neither the weather nor the work required of them, however, was beyond their powers using the equipment, food, and supplies furnished. The men also had a lot of time for tending to their water requirements. Nevertheless, on certain days, some men appeared to excrete no more urine than was necessary to eliminate the dissolved substances. Under more severe conditions, some men would very probable allow themselves to dehydrate. Indoctrination might be of no help, for the observers themselves were governed more by the stimuli of the moment than by their knowledge of water balance.

From their personal experience and the data collected, the observers wish to emphasize that cold alone would not solely be responsible for causing dehydration in the field. Many factors would interact in a complicated manner and the net result could be ascertained only by measurement in the field. Some of these factors would be: (1) ambient temperature, (2) wind, (3) equipment for procuring water, (4) time available for procuring water, (5) sweat production, (6) fatigue and exhaustion, (7) amount of water, salt, and protein in the food, (8) terrain, (9) psychological characteristics of the individual and of the group and finally (10) duration of the field exercise.

Each of these factors in turn is general and not particular. Sweat production is determined not only by cold and work, but also by the ventilating properties of the clothing, whether or not it is easier to wear clothing or to carry it on the pack, etc. A stove capable of melting 500 cc. of water from snow in 45 minutes may be leaded up by repeated use. An ax is superior to a heel for breaking through surface ice. Clearly, predictions of water intake based on climatic maps and table of equipment will at best be but approximations.

IV. SUMMARY

Twelve men at Task Force Williwaw over 4 days, and 11 men at Task Force Frigid over 5 days maintained water balance. Water was obtainable only from natural sources.

The weather and work were not too severe, and the food, equipment, and time for procuring water were adequate enough to make it not too difficult to stay in water balance.

About half of the water intake was from food but, in some cases, the urinary volume although moderately high was only enough to excrete the excess salt and protein metabolites.

The possible importance of the water balance problem in arctic field operations is pointed out.

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PART III

FOXHOLE STUDIES

I. INTRODUCTION

A 48-hour foxhole test was planned for both Task Forces but only the one for Task Force Williwaw was performed. At Frigid, foxholes could have been prepared only by blasting procedures. Other factors and considerations also intervened to make it seem advisable not to attempt a test at Frigid.

Some of the fundamental considerations for the Williwaw test were along the following lines. As long as men are supplied with adequate protective equipment they have no particular difficulty enduring a wet-cold environment. This was proved by the 5-day mountain exercises during which the water-balance data were collected and later by the foxhole test performed by the Task Force in February. The observers were interested in studying men, not equipment, and it did not seem profitable to conduct a test which did not submit the men to the rigors of the environment.

During the preceding December field exercise when the troops were in bivouac, a terrific williwaw blew down the tents and the men abandoned their equipment and retreated to the base camp. What would have happened physiologically to the men, if the enemy had intercepted their retreat and forced them to dig in without their protective gear? In the January mountain exercise, the men broke column on the return march and went into firing positions. Before doing so, however, all dropped their heavy packs and left them behind. If the exigencies of combat had then called for a sudden advance down into the valley with subsequent interruption of the supply line, how well could they have endured protracted exposure without the benefit of extra personal equipment? The tundra of the North is barren of trees, farmhouses, barns, etc., which could be adapted to one's needs, and it is not inconceivable that in combat over the wastelands men could be cut off from their supplies and equipment for a significant period of time.

Having learned by observation over a period of 10 days in the field that the test subjects suffered no undue strain in the wet and windy cold environment of Adak, it seemed worthwhile to the observers to test the potentialities of these same men when certain standard items of equipment were withheld. Foxholes provided both logical and convenient devices for holding the men relatively immobile in the wet-cold environment.

II. EXPERIMENTAL

A. Objectives

The general objective was to ascertain the physiological strains which are induced by protracted exposure in a wet-cold environment. To this end, the following physiological observations and measurements were made: (1) skin and rectal temperatures, (2) heart rate, (3) kidney function, (4) water and food intake, (5) fatigue and the ability to rest and recover and (6) subjective reactions.

B. Materials and Methods

The test was performed on a plateau of Mount Moffett on Adak Island on 26 January 1947.

The subjects were 8 enlisted men and 1 first lieutenant of an infantry company. Their clothing was the same as that worn in the water-balance study previously described. They were also permitted to put on wet-weather parkas and trousers, but were prohibited the use of foxhole covers, sleeping bags, and accessory heat except canned heat issued to warm the E Rations. They were all well rested, fed, and warm before starting the test; no one was suffering the after-effects of alcoholic intoxication. Food was given every 6 hours, but water was dispensed in measured quantities as part of the diuresis tests. Candy bars and cigarettes were freely available, but were infrequently requested.

Preliminary measurements, including nude and clothed weights, pulse rate, and body temperatures were made in a warm hut near the foxholes. The temperatures were measured in the same manner as in the Eskimo studies. As soon as these preliminary procedures were completed on a man, he went out and entered his foxhole but, inasmuch as it took about 3 1/2 hours to complete the procedures on the 9 men, they did not start their exposures simultaneously. Two men were in each of 4 foxholes, but the officer was in the fifth foxhole by himself. They were under strict orders to remain in their foxholes for 48 hours, unless the observers found undue strains arising and called them out individually.

C. Results

1. Weather. Measurements of air temperature and wind velocity (with a totalizing anemometer) were made every 10 minutes until about 0030 hours. During this time the air temperature at 3 feet above the ground was 28°F. to 30°F., and at the bottom of the foxhole it was about 30°F. to 32°F. The wind velocity averaged about 30 miles per hour until midnight, when it rapidly increased. The average velocity for the last 10-minute period for which a measurement was made was 72 mph. (which means that at times it was even higher). The men in the foxholes, however, claimed that the wind had negligible cooling effect, although it was annoying because of the dirt and snow it blew into their faces and food. The sky was always completely overcast, and at about 1700 hours (about 8 hours after the exposures started) snow began to fall. At the time the test was terminated, about 10 1/2 hours later, the foxholes were half filled with snow.

The above figures give an inadequate description of the weather, and it is therefore difficult for one sitting in a comfortable chair to appreciate the full fury of the storm which descended upon the test. The roaring and blinding wind and snow restricted vision to a few feet and made verbal communication nearly impossible. Useful observations could not be made until the storm had abated. In the meantime, all that the observers and their assistants (a sergeant and a corporal) could do was make periodic visits to the foxholes and attempt to encourage the men to carry on.

2. Endurance. Five men were unable to endure these conditions for more than an average of 16 hours (15.4 to 17.4 hours). They left their foxholes individually (in 3 cases without knowledge that anyone else had done so) and retreated to the hut, which they must have entered not without some hesitation for they did not know what reprimand awaited them. They all looked very wet, but they were not asked to strip to be weighed because the hut was cold. (The wind had blown snow into the heater, which was outdoors, and had stopped it at about midnight.) Thus no measure of the amount of moisture in the clothing was obtained. The outer garments were removed, and the men wrapped themselves in blankets and just sat and shivered until they were taken back to quarters. They all drank hot coffee and some ate candy bars.

When the fifth man abandoned his foxhole at 0330 hours, the observers decided to terminate the test and they called in the remaining 4 men. These had stayed out an average of 16 hours. In the subsequent interrogation, made individually a day later, they estimated their further endurance as follows: 4 more hours for 1 man, 12 more for 2 men, and the full 48 hours for 1 man. Adding these estimated additional hours to the 16 hours the men had actually stayed in the foxholes, one obtains the following distribution of probable endurance times for the whole group: 6 men could endure only 15 to 20 hours; 2 men could endure about 30 hours; only one man thought he could last 48 hours. The notable feature of this distribution is that it is skewed to the range of short endurance.

It is worthwhile at this juncture to re-examine the environmental conditions which caused the men to stay in their foxholes for 16 hours and then to leave them in a hurry The stimuli can be classified in 2 groups: those which inhibited flight and those which stimulated flight from the foxholes. In general terms they were are follows:

a. Stimuli which inhibited flight:

(1) The military order to stay in the foxhole until told to get out.

(2) Social stimuli which encourage one to "take it" and discourage yielding to unpleasantness.

(3) The knowledge that the test would not last forever, and that the observers would terminate it before deleterious effects supervened.

(4) Minor stimuli such as those of personal relationship between observers and subjects, interest in helping science, etc.

b. Stimuli which excited flight:

(1) Persistent cold.

(2) Wetness, which was disliked independently of its cooling effects.

(3) Stiffness from uncomfortable posture.

(4) Wind noise.

(5) Proximity of the hut, presumably warm though actually it was not after midnight. Only one subject admitted the force of this stimulus; one was uncertain on the matter and 3 would have left their foxholes even in its absence.

(6) The probability that disobedience would not meet with severe censure. One subject was not asked about this matter and no entry was made as to another's response. Three men said only positive foreknowledge of a severe court-martial penalty would have forced them to stay in longer.

These two antagonistic sets of stimuli were acting continuously. At first the inhibiting set was prepotent, but gradually over 16 hours the second set summated and suddenly caused flight. Undoubtedly, "fatigue" had something to do with lowering the threshold to the excitatory stimuli. How powerful this summation finally became may be gauged by the assertion of 4 men that even enemy fire would not have been an adequate stimulus to inhibit flight. As one subject put it, "All right, you'd be shot and dead and gone. You wouldn't have frozen feet no more."

In further discussion the 5 men who abandoned their foxholes will be referred to as Group 1; the 4 men who stayed in the foxholes will be called Group 2. The data will be considered to see if they shed any light on why Group 1 reached the limit of endurance and Group 2 did not. Since all observations were stopped about 1 to 3 hours before the men left their foxholes, the data do not give information about the final critical moments. Nevertheless the data for the first 14 hours are instructive.

3. Body Temperatures. The first conjecture that comes to mind as to why Group 1 left their foxholes is they they did not maintain their body temperatures as high as the men in Group 2 did. As an example of the results obtained, the measurements on subject 13 are shown in Figure 2. They are particularly interesting because this man stayed in his foxhole for the shortest length of time (15.4 hours). Attention is called to the following notable features:

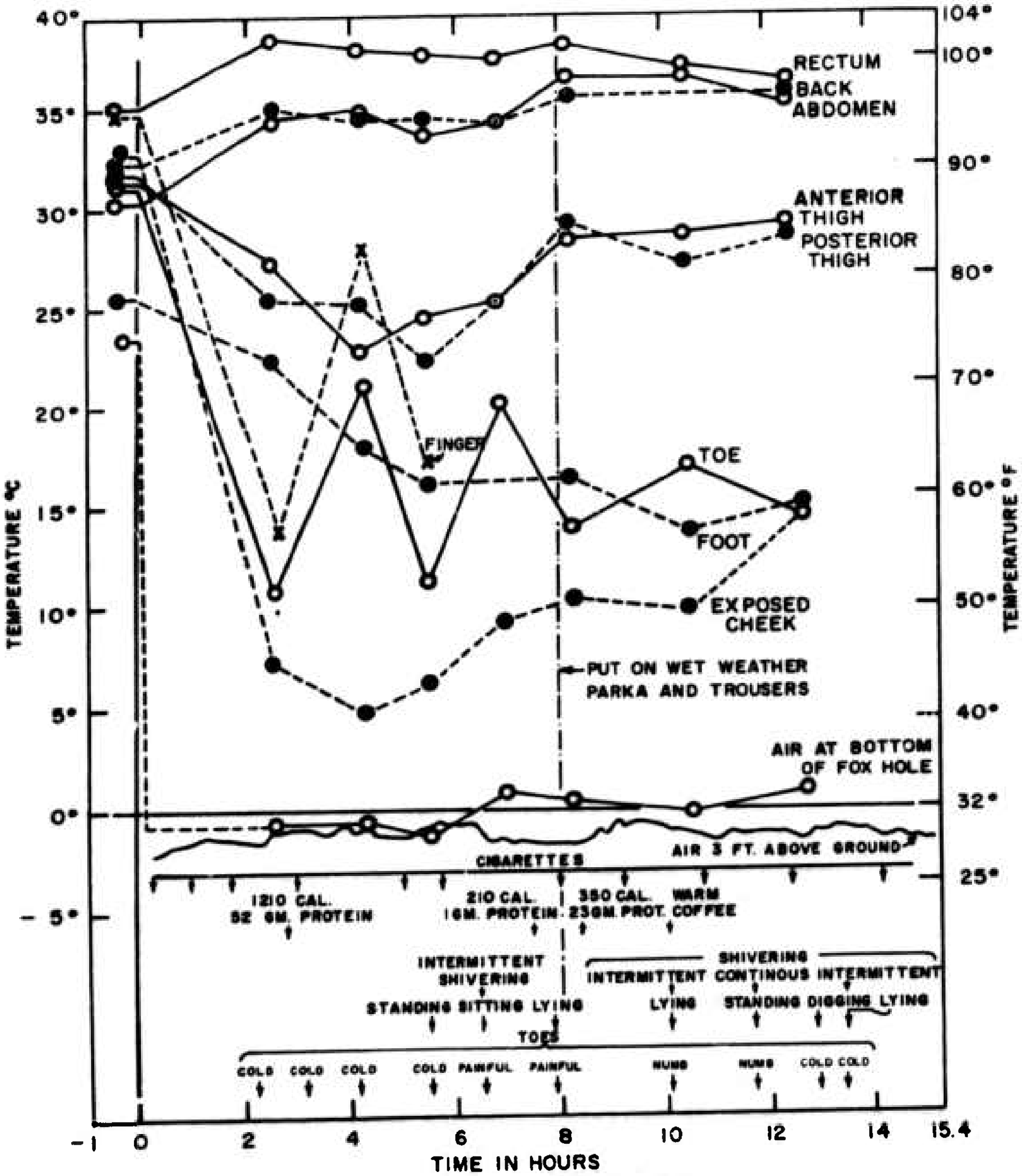

FIG. 2 BODY TEMPERATURES OF SUBJECT NO. 13

HE ETERED FOXHOLE AT 0 HOUR; ABANDONED IT AT 15.4 HOURS.

a. The temperatures of the trunk were maintained at a high level. The skin over the back and abdomen warmed up after the wet-weather clothing was put on, but the rectum showed signs of slight cooling during the last two hours of measurement.

b. The thigh skin cooled upon exposure but remained between 72° to 78°F. and warmed up to about 84°F. after the wet weather clothing (parka and trousers) was put on.

c. The coldest part of the body was the exposed cheek.

d. The foot (in 3 pairs of socks and shoepacs) cooled slowly over five hours and leveled off at around 60°F.

e. The temperatures of the finger and toe oscillated; unfortunately, the finger couple broke early in the test. The toe warmed and cooled between 50° and 70°F., with 60°F. as an approximate mean. This periodic fluctuation in the temperatures of the extremities shows no obvious correlation with food intake, activity, or smoking. Miller (1943) obtained similar temperature rhythms of the digits in cold room experiments (-40°) lasting up to 8 hours; he offered no explanation in his brief report.

As compared with the results in Figure 2 for subject 13, the other 8 men showed the following general picture:

a. All maintained high trunk temperatures.

b. The cheek was usually not the coldest part of the body.

c. The finger and toe showed only one or two oscillations.

d. The extremities cooled to the following levels: in Group 1, two men averaged around 60°F. and three around 55°F. in Group 2, two averaged around 60°F. and two around 55°F.

Thus, the evidence does not permit a differentiation between the two groups on the basis of body temperatures.

4. Subjective Reactions. Even though all of the men showed approximately the same general temperature responses during their exposure, it is possible that the men of Group 1 felt subjectively colder than those of Group 2. Each time the pulse was counted the subject was asked how he felt on the following parts of the body: toes, feet, knees, fingers, hands, and face. The subject answered in one of the following terms for each part: cool, cold, painful, or numb. If he did not feel even cool, it was assumed that he felt comfortable in that part of the body.

To an overwhelming extent the men were uncomfortable mostly in their toes, at least during the time that the data were collected. This is surprising because the toe, finger and cheek temperatures were usually at the same level. The data for the toes are given in Table 13.

TABLE 13

SUBJECTIVE REACTIONS FOR TOES

Hour of Exposure	SUBJECT NUMBER								
	2*	3*	4	5	6*	7*	8	9	13*
0 - 1	—	—		—	—	—			—
1 - 2	Cold	Cold					Cold		—
2 - 3	Cold	Cold		Cold	Cold		Cool		Cold
3 - 4	Cold	Cold		Cool	Cold	Cold	—		Cold
4 - 5	—	Cold	—	Painful	Painful	Cold	Cold		Cold
5 - 6	Cold	Cool		Painful	Cold	Cold	Cold	Cool	Cold
6 - 7	Cold	—		Cold		Cold	Cold	—	Painful
7 - 8	Cold		—	—	—	—	—	—	Painful
8 - 9	—	—	Cool	—	—	—		Cool	—
9 - 10			—		Cold	Cold	—	Cool	—
10 - 11	—				Cold	Cold	Cold	Cool	Numb
11 - 12		Cold			Cool	Cool	Cold	Cold	Numb
12 - 13	Cold	Cold	Cold	Cool	Cool	Cool	Cold	—	Cold
13 - 14	Painful	—	—	—	—	—	—	—	Cold

Blank spaces, comfortable
—, no record
* Abandoned foxholes

If a report of cold, painful or numb is considered as very uncomfortable, then the men of Group 1 averaged very uncomfortable in their toes 7 out of the possible 10 times that they could report their feelings. Group 2 averaged great discomfort 4 out of the possible 10 times. Thus, on the average, those who left their foxholes felt colder in their toes than those who stayed in to the end of the test, although there was a slight over-lap between the two groups.

As to the other parts of the body, for a total of 60 possible reports (10 times for each of 6 parts of the body) Group 1 reported very uncomfortable for an average of 14 times (10, 11, 14, 16 and 18); Group 2 averaged 6 reports of very uncomfortable (1, 1, 10, and 11). These averages appear to be low; unfortunately, the notations were stopped 1 to 3 hours before the end of the test. Naturally, the men of Group 1 claimed that in this time they became very cold; at any rate, they were too cold to sleep. The general conclusion is that Group 1 felt colder, or reported they felt colder, than Group 2. Subjective reporting does not correlate with temperature measurements. (See Fig. 2.)

5. Activity. Since the clothing and environment were approximately the same for all of the men, the fact that their several body temperatures were similar indicates that they all were producing by oxidation about the same amount of heat. It is interesting to note whether or not the two groups can be differentiated as to the predominant mode of heat production - shivering or coordinated muscular activity. Activity ranged from digging to sleeping. Digging consisted of deepening the foxhole or excavating a lateral tunnel. On occasion, the men stood up and moved around for the sake of "taking the stiffness out of their joints"; in other words, cold was not the sole stimulus for increasing heat production.

Notations on shivering and activity were made 7 times, about once per hour, starting after about 5 hours of exposure. If intermittent shivering is scored as 1 and continuous shivering as 2, then the observed shivering averages 3.2 for Group 1 and 0.75 for Group 2. Thus, Group 1 shivered about 3 times as much as Group 2, roughly speaking. The observed activity was scored as follows: lying, 1; sitting, 2; standing, 3; digging, 5. Group 1 had an average activity score of 17 (14 to 20); Group 2 averaged 25 (21 to 28). Thus, by the evidence obtained, Group 2 was about 50% more active than Group 1.

The above data on shivering and activity are indeed rough and fragmentary, but they were obtained without conscious bias for the observers had no premonition that certain men would quit and others would not or that the test would terminate so abruptly. For this reason, it would seem that more than chance or bias was operating to give the above indications that Group 1 produced extra heat more by shivering than Group 2 did, whereas, the latter were more active than Group 1.

As to fatigue, no quantitative evidence was obtained to differentiate the two groups. Naturally, as the night wore on, all men became very tired. How can fatigue be measured, especially in foxholes during a storm? Analyses for adrenocortical steroids in the urine might have given some information. It is significant to note, however, that the limit of endurance was reached at that time of the diurnal cycle when one usually tends to feel tired and weak, and not at an earlier or later time.

Only one man was able to sleep; he was in Group 2. At 0130 hours he curled up in his tunnel and slept until ordered out at 0330 hours. It is probably significant that he was the only one who ate his midnight ration, which included 690 Calories, 24 grams of protein, and 500 cc. of warm coffee. Two more men tried to sleep after midnight, but could not continue beyond about 30 minutes because the cold woke them. The remaining six men felt too cold even to try to sleep. Thus it cannot be said that the men of Group 2 had greater endurance than those of Group 1 because the former were able to restore the physiological mechanism by sleeping.

6. Heart Rate. Figure 3 shows the pulse rates for the subject with the highest, and for the subject with the lowest counts, both in Group 1. All other subjects had heart rates intermediate between these two extremes; the average for the 9 men was about 80 beats per minute. The highest count obtained was 120, and the lowest was 52, each only once (Fig. 3). The results do not indicate cardiac strain or violent shivering, which has been found to be correlated with acceleration of the heart in nude men (Adolph and Molnar, 1946). No correlation was found between heart rate and endurance.

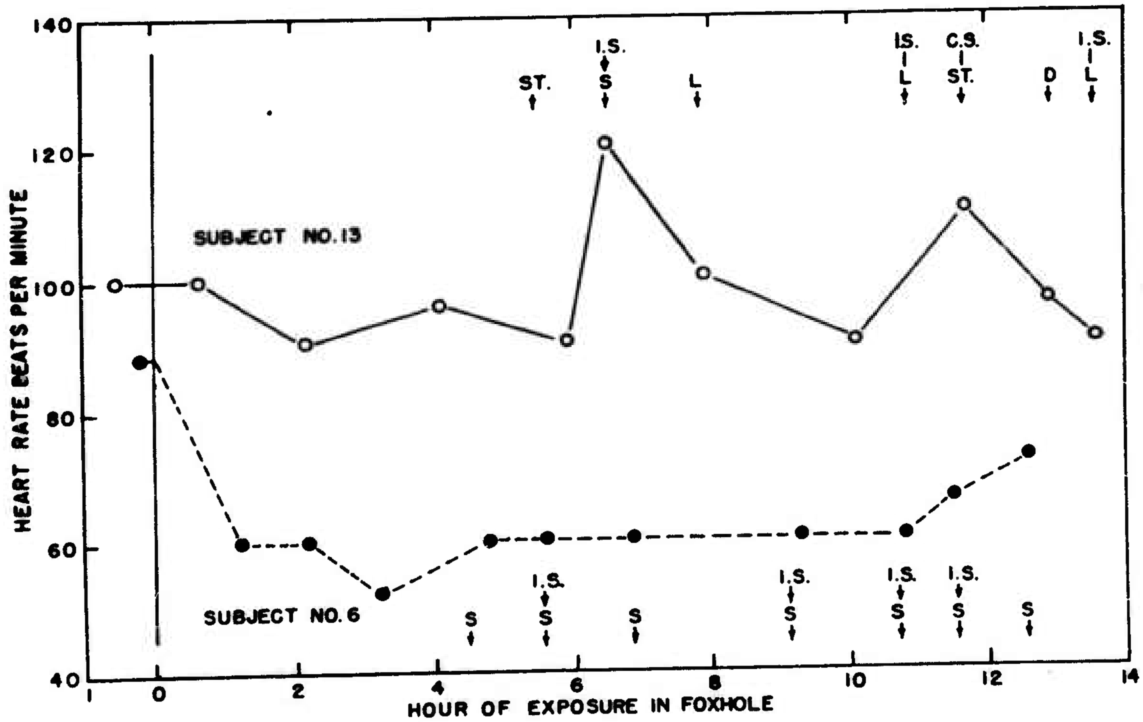

Fig. 3. Heart rates of two men having highest and lowest values. All other men had intermediate rates. S = sitting; ST = standing; L = lying; D = digging; I.S. = intermittent shivering; C.S. = continuous shivering.

7. Kidney Function. The details of all of the kidney function tests (simple water or coffee diuresis) performed on Adak will be described in a separate report. Some of the results are shown in Figure 4. They suggest that initially upon exposure to cold there is a rapid diuresis even when no fluid is ingested. After more than three hours of exposure, however, there is no diuresis unless fluid is ingested and the diuretic response to 500 cc. of water is not great. Similar results were obtained with coffee. It would have been difficult to force the subjects to drink more than 500 cc. in the cold. No correlation could be found between the diuretic response and endurance. Despite the low response to 500 cc. of fluid, however, the total output for the day by the kidneys was adequate, as will be shown below.

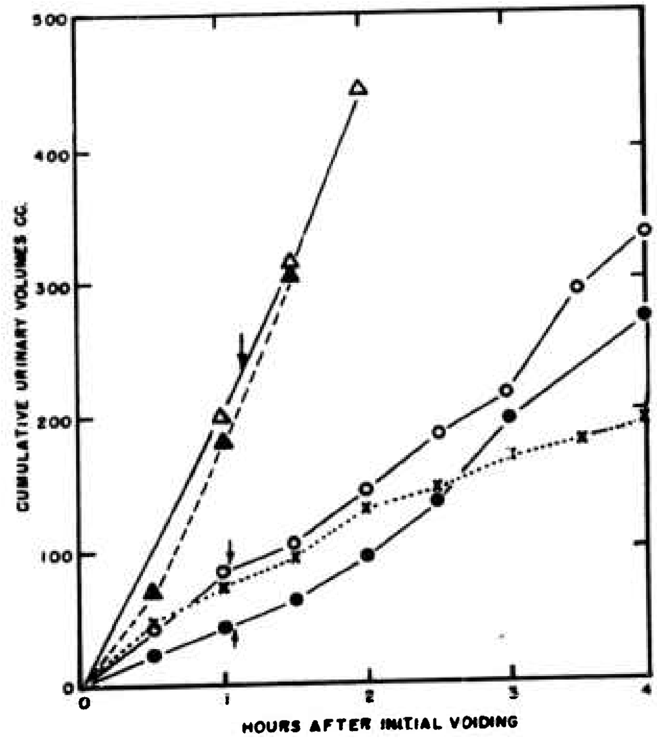

Fig. 4. RESULTS OF WATER DIURESIS TESTS

o = Mean for 3 subjects who drank water; initial voiding 3 hours after entering foxholes.

● = Mean for 3 subjects who drank water; initial voiding 9 hours after entering foxholes.

x = Non-drinker; initial voiding 5 hours after entering foxhole.

△ = Mean of interpolated values from curves of earlier test on drinkers sitting outdoors. Exposure at 0 time.

▲ = Mean of interpolated values from curves of earlier test on non-drinkers sitting outdoors. Exposure at 0 time.

Ingestion of water at time indicated by arrows.

8. Water and Caloric Intake. The mean values for fluid and caloric intakes and urinary outputs are summarized in Table 14. The data were collected over a period of about 22 hours, of which about 16 were spent in the foxholes. The men of Group 2 ate more food than those of Group 1, as can be seen from both the number of calories ingested and the amount of water in the food. Group 2 ingested about 1100 Calories more than Group 1, on the average, although one man in Group 1 ate about the same number of Calories (3010) as on the preceding days. The amount of fluid drunk while in the foxholes was the same for both groups since it was dispensed in measured quantities. There was no significant difference between the two groups as to urinary volume, specific gravity, or total solids. Water balance was maintained by all and the kidneys apparently excreted both water and solids normally during the exposure.

TABLE 14

WATER AND CALORIC INTAKE AND URINARY OUTPUT IN FOXHOLE TEST

Mean Values for about 22 Hours

Number of Men	GROUP 1 Abandoned Foxholes	GROUP 2 Ordered out of Foxholes
	5	4
Time in Foxholes	16.07 hours (15.42 to 17.42 hours)	16.15 hours (15.58 to 16.50 hours)
Caloric Intake	2445 (2170 to 3010)	3530 (3160 to 3930)
Water Intake		
Drink	1.47 liters	2.03 liters
Food	0.80	1.07
Oxidation*	0.31	0.47
Total Intake	2.58 liters	3.57 liters
Urinary Output		
Volume	1.37 liters	1.51 liters
Sp. Gr.	1.020	1.020
Total Solids	67 gm	78 gm

*Calculated on the basis of ingested food.

9. Emotional States. It is generally considered that the mechanisms of the body which give rise to some of the emotional responses have had, during the course of evolution, survival value by putting the organism in instant readiness to cope with emergencies. Since during the terminal hours of the test an emergency situation existed by all the ususal standards, it is interesting to inquire how the two groups of men responded emotionally. Heightened activity of the emergency mechanism of the body

produces certain characteristic responses. Those for which some information was obtained were as follows:

a. Hunger. It is notable that 4 of the 5 men in Group 1 had reduced food intakes during the course of the day. The plausible inference is that their stomach contractions were partially inhibited by heightened sympathetic discharges. By midnight, however, 3 of the men in Group 2 also were not hungry, for only 1 of them ate his ration at that time. It is clear that hunger was not a stimulus which caused flight; instead, the absence of hunger indicates that the emergency mechanism was in operation, and more so in Group 1 because they ate less during the day.

b. Anger. Some evidence was obtained indicating that 4 men in Group 1 were angry at their plight; the fifth was probably not. In Group 2, 3 men were not angry and the fourth was probably not. It follows that the emergency mechanism was probably more active in Group 1 than in Group 2.

c. Sleep. Sleep involves general relaxation and perhaps inhibition of certain parts of the hypothalamus; in other words, during sleep the emergency mechanism must be at a low ebb. Only 1 man (in Group 2) was able to sleep; hence, the two groups cannot be differentiated on the basis of tenseness.

The data on emotional states are clearly inadequate, but they are presented to emphasize the importance of psychophysiological aspects which are generally not properly studied. As a rule, a physiologist investigates that which he can readily measure, e.g., the pulse, skin temperature, urine, etc. Yet the factors which determine performance and endurance may be of a more subtle nature than heat balance, water balance, etc. Clearly, the relatively unexplored field of psychophysiology requires development. Perhaps the first approach should be the adaptation of present physiological techniques to the subtler problems. For example, although knowledge of body temperatures is important, it is perhaps more important to know about frequencies of digital vasodilatations which could be deduced from more frequent temperature measurements.

10. Miscellaneous Information.

a. Physical data. There was no significant difference between the two groups as to: (1) age - average for Group 1, 23; for Group 2, 21; (2) weight - average for Group 1, 152 lb.; for Group 2, 154 lb. There was no extraordinarily large man in the test; the heaviest was 168 lb. (in Group 2); (3) height - average for Group 1, 68.5 inches; for Group 2, 67.8 inches.

b. Intelligence and education. Unfortunately, the AGCT scores were not obtained. The observers guessed that the men had about average intelligence. Excepting the officer, the two groups had about an even amount of schooling.

c. Origins. The men in Group 1 were born in Arizona, Oklahoma, Texas, West Virginia and New Jersey. Those in Group 2 were born in Tennessee, California, Colorado and West Virginia. Thus none of the subjects were born in the northern states; on the other hand, complete life histories were not obtained and it is possible that some of the men were reared in the northern states.

d. Previous experience. All of the men had arrived on Adak 5 months before the test and had taken part in the Task Force's field exercises. They thms had an equal opportunity to become acclimatized to the conditions of Adak.

Four of the 5 men in Group 1 had been in combat (ETO) for 3 to 12 months. In Group 2, one man had been 4 months in combat (ETO), 2 had not, and no entry was made for the fourth man. It appears that those with more combat experience had less endurance than those with little or no combat experience. The subject with the shortest endurance but the longest combat experience (12 months) had this to say, "The experiment conducted on Adak, 26-27 January 1947 was, in my opinion, one of my most harrowing experiences. I have been in worse positions, been colder, and have been wetter, but very few times. This experiment compares favorably with some of my most miserable experiences, minus the threat of the enemy."

III. DISCUSSION

The chief result of this study is that of the 9 men who successfully carried through for 5 continuous days in the field, 5 men were unable to endure similar conditions for more than 16 hours when movement was restricted and certain protective items were withheld. Their endurance seemed to be limited not strictly by physiological factors (thermal balance, cardiac strain, kidney function, etc.) but by psychophysiological factors (heightened activity of the emergency mechanism). The probable practical military implications are that in environments similar to that on Adak: (1) The men should be relieved every 12 to 16 hours, or (2) measures should be taken in time to insure that all men have their protective gear, or (3) men should be preselected for their endurance, or (4) endurance should be prolonged by methods yet to be worked out.

The following criticisms can be directed at the test:

1. There were too few subjects to permit generalization. It seemed more important to the observers to study a few men intensively than to squander their efforts superficially over a host of men. The object was not to prove the universality of a generalization, but to discover significant physiological strains even if they occurred only in individual cases. It must also be realized that a careful field study requires incomparably more work than a laboratory test.

2. Older and more experienced officers could have held the subjects to their duties for a longer time than the observers succeeded in doing.

The observers entertain no delusions about their ability to command. On the other hand, the observers do maintain that they did secure the full cooperation of the men during the preceding 10 days in the field and that the men broke only when the situation became extraordinarily severe. Furthermore, a soldier is trained to be a soldier and not a test subject; the observers, therefore, had to supplement military procedures in order to attain their end. Finally, from personal conversations, the observers gathered that when the infantry found itself in a situation comparable to the foxhole test, namely, when the December williwaw blew down the tents and exposed the men in the early hours of the morning, the responses of the men were such that the field exercise was terminated. These men were not in charge of observers. The great difficulty in controlling men in a blinding windstorm is that of verbal communication.

3. A soldier always sees to it that he is as comfortably ensconsed as possible and, therefore, the test conditions were unrealistic. This generalization must be based on experience in environments which can supply something, if only boughs, straw or farmers' blankets. A desolate wasteland, however, is completely barren. Moreover, in the test all of the men could have made themselves more comfortable by digging lateral tunnels. Four of the subjects (2 in each group), however, did not even attempt this, and the 5 men who did excavate could have made far more comfortable tunnels. The results of the test do not bear out the contention that a soldier always makes himself comfortable.

4. The subjects should have been offered some distraction, such as cards or ammunition to fire. Cards were not prohibited, but it would have been impossible to play cards in the dark and in the snow. Firing was out of question, but do soldiers always fire ammunition for amusement when they are biding their time in foxholes? Finally, one subject expressed his annoyance at the chief distraction of the day - the frequent visits of the observers or the assistants. He justed wanted to sit and not be bothered.

5. Combat is such a frightening experience that it can keep men in foxholes even under the severest environmental conditions. This possibility is real but cannot be tested in peacetime. Most accounts of war experiences tend to become anecdotes, and often do not give accurate information to the critical mind. Finally, in this particular test the men with combat experience tended to make a poorer showing than those without it; in fact, the subject who had had the most exposure to combat found the test one of the worst ordeals of his life.

IV. CONCLUSIONS

A. Men in a wet-cold environment are not under as severe stress as men in a dry-cold environment. Wet-cold, however, does impose limitations on endurance but not by direct and immediate action, such as rapid cooling and freezing, but by indirect influence over a period of hours. Many stimuli, e.g., wetness of fingers, unimportant in comfortable environments, summate with the passage of time and elicit overt responses which indicate the limit of endurance. Psychophysiological factors play a more prominent role than purely physiological factors. The temperatures of even the extremities do not approach freezing but their discomfort summates with other factors to limit endurance.

B. Preselection of men for duty in wet-cold environments should be based on factors which correlate with endurance. The results of this study suggest that men who report that they feel cold, shiver more than move around, have inhibited appetites in the cold and are easily provoked to anger are poor risks.

C. Measures for prolonging endurance should be directed at the factors which summate their influence and thus bring endurance to a halt. The value of other expedients, e.g., food, drugs, horomones, etc., should be explored.

D. Protective items (clothing, heating devices, etc.) are very practical measures but they do not increase one's innate endurance. They serve by walling off the man from the unbearable environment. When they are not available, the brunt of the stress bears down upon him.

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GENERAL REMARKS

1. Man has not yet conquered the cold North in the manner of the polar bear. He was merely inserted little pockets of heat from which he occasionally sallies forth. Even the Eskimos do not live continuously in the cold. These obvious statements carry a practical implication sometimes overlooked. If there is such a thing as physiological acclimatization to cold, it occurs in the natural world as a result of intermittent exposure. Continuous exposure may or may not hasten the process, but laboratory experiments designed to study it are more realistic, if they utilize intermittent exposures.

2. Merely to carry on ordinary living in the North requires a lot of work; any further accompishment involves an extraordinary expenditure of effort. It follows that manpower demands are high.

a. The commanding officer of Task Force Frigid stated that he thought the unit of operation should be, not the individual, nor even a pair of men, but 5 or 6 men. They would, of course, assist each other in moving individual equipment, making and breaking camp, etc., but equally important, they would reduce the element of fear, especially of becoming a lost casualty. The group would perform the task ordinarily assigned to one or two men.

b. It is evident that these ideas of operation are more comprehensive in scope than those which consider merely the decrement in efficiency due to cold alone. Man's over-all efficiency in the field is reduced, not merely because of the cold, but also because of all the additional things which have to be done because of the cold. Time is lost packing and transporting extra personal gear; wiping one's nose; trying to find an object dropped in the snow; scraping the snow away to mount something; watching one's step to avoid slipping and breaking (and perhaps freezing) a limb; dancing around to warm up, etc. None of these activities reduce the dexterity of a particular manipulation, but they probably go further in reducing the total useful accomplishment in unit time than decrement in dexterity.

While watching men operate in the field, it is difficult for an observer to avoid the conclusion that laboratory psychomotor tests have but little bearing on the problem of calculating manpower needs. The laboratory tests are necessary for laboratory purposes - e.g., for determining the best location of a knob on an instrument panel. For field problems, however, it is best to set up field experiments.

c. The difficulties and extraordinary work involved in conducting field observations on men are apparently not sufficiently appreciated. It is particularly important that the chief observer should not be forced to restrict his attention to a single series of measurements but should be free to oversee all aspects of the test.

3. Without a doubt, it is essential to supply men with hot food in the Arctic but if the Army is not going to operate beyond field kitchens,

its range of activities will be limited. One is especially convinced of this possibility when looking down upon such a place as the Brooks Range from an airplane. The development of a good Arctic field ration seems to be indicated. The present E Ration does not fill the bill, nor would a survivor's ration of a limited number of calories be adequate. A good Arctic field ration should be high in calories, high in water and moderately low in ingredients (proteins and salts) which raise the urinary volume. It should, of course, be acceptable. It is possible that one can eventually learn to subsist on a diet of caribou, or something, but during the learning period difficulties will develop and by the end of the period one may be back at a kitchen. After a few days on E Ration, most men restrict their choices to a limited number of items, and these acquire a uniform taste. Many men also complained that there was nothing to chew on in the meat ration; it was nothing but a homogeneous soft mixture.

The following suggestions are offered for consideration:

a. The bulk of the calories should be in foods like cookies and crackers, which can be nibbled at frequent intervals without need for heating. They should have enough binding to prevent cracking and crumbling. The present fudge candy is too hard to bite, unless first warmed against the body for several hours.

b. Water should be supplied, as in the E Ration, in the meat and fruit. The meat should be in the form of chunks, larger than dice, and associated with discrete chunks of carbohydrate (potatoes, macaroni, etc.). The cans should be rectangular in shape, like a sardine can, and perhaps bisected by a partition with meat in one half and potatoes in the other.

c. The gasoline stoves should be more easily ignited than the present one-man stove, and should lose less heat to the environment. The food can could be placed in an insulated well with a cover. It should be possible to eat directly from the stove.

d. A large can-opener and spoon should be part of the individual equipment. All packages should be easily opened with mittened or, at least, gloved hands.

4. The behavior of the gastro-intestinal tract in the field ought to be studied. Appetite, inhibition of hunger, ability to drink cold water, constipation and impaction, flatulence and "heart-burns," etc., may all influence performance to a greater degree than cold <u>per se</u>. No doubt, explorers, trappers, Eskimos, etc., are able to carry on without all these investigations. They form a group, however, who have been screened by natural selection. We are concerned with the performance and well-being of a heterogeneous group of men who are removed from a comfortable environment, where they had developed very fixed habits, and are thrust into the Arctic.

5. Perhaps one of the most important problems of the Medical Department is the cause of death in hypothermia. Significant reduction of deep body temperature does not occur with active men. It would, however, take place with exhausted or wounded men, unless help was quick in coming. Man dies long before he freezes. If he could take something that would counteract the causes of death and keep him alive until he did cool to 32°F. (instead of just 75° to 85°F.), many lives could be saved.

Body cooling is accelerated even on Adak, where the air temperature is not low, but the ground is wet and the wind velocity high. Indeed, the "wind-chill" may be as great there as anywhere. Many parts of the Arctic during spring and autumn have weather like that on Adak. Moreover, when the temperature is above freezing there are many pools of water. Immersion hypothermia occurs rapidly (Molnar, 1946), and is as much a problem for the Army as for the Navy.

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